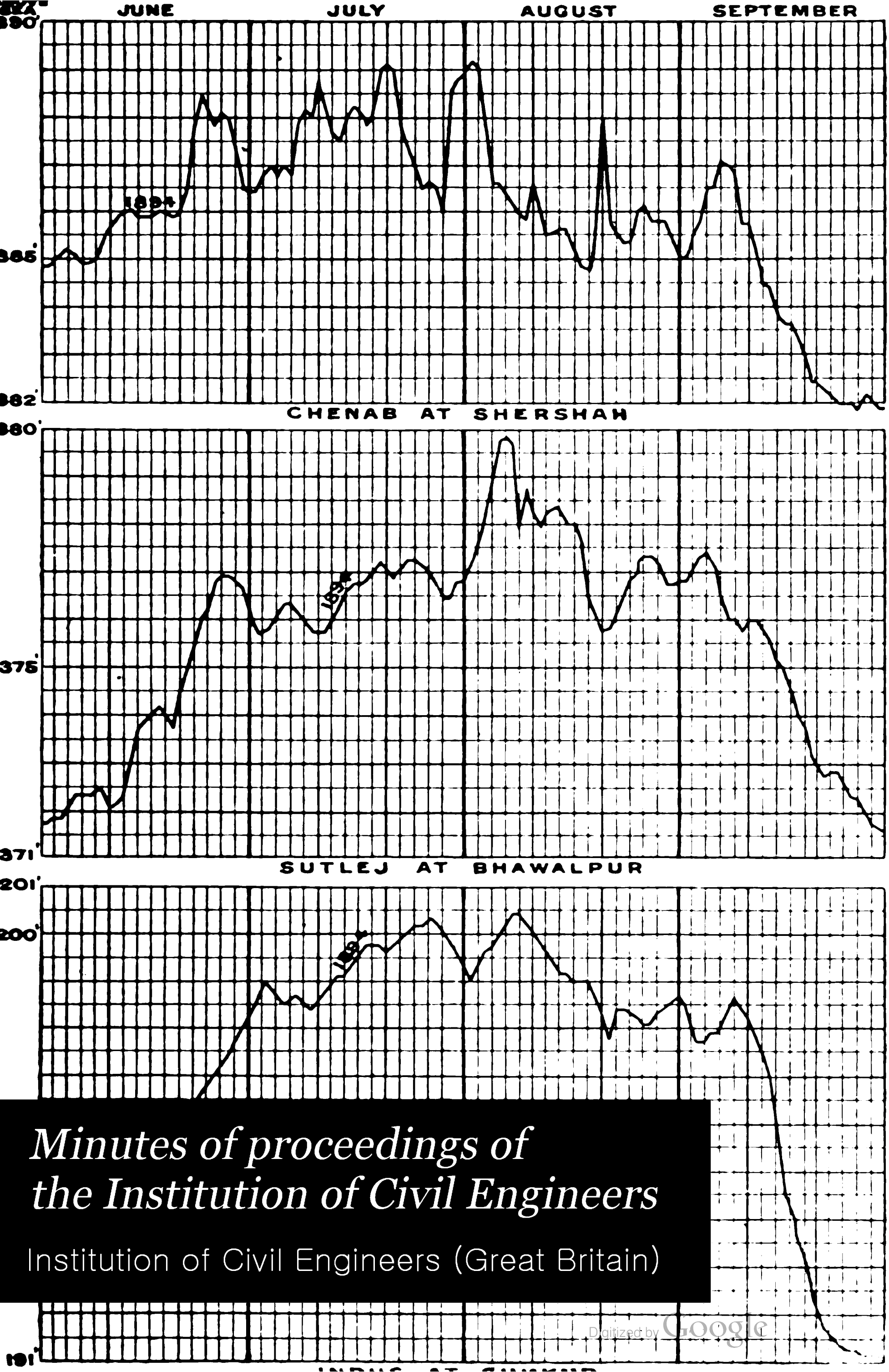

Minutes of proceedings of the Institution of Civil Engineers

Institution of Civil Engineers (Great Britain)

MINUTES OF PROCEEDINGS

OF

THE INSTITUTION

OF

CIVIL ENGINEERS;

WITH OTHER

SELECTED AND ABSTRACTED PAPERS.

VOL. CXL.

EDITED BY

J. H. T. TUDSBERY, D.Sc., M. INST. C.E. SECRETARY.

LONDON:

Published by the Institution,

GREAT GEORGE STREET, WESTMINSTER, S.W.

[TELEGRAMS, "INSTITUTION, LONDON." TELEPHONE, "WESTMINSTER, 51."]

1900.

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Great George Street, Westminster, S.W.

LONDON: PRINTED BY WM. CLOWES AND SONS, LIMITED, STAMFORD STREET AND CHARING CROSS.

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CORRIGENDA.

Vol. cxxxvii. p. 112, lines 26, 27, the wording should be transposed so as to read "12*s*. 8*d*. per ton as compared with 15*s*. 2*d*. per ton at Middlesbrough."

" " " line 29, *for* "3*d*." *read* "5*d*."

" cxxxix. p. 143, line 1, *for* "Simens" *read* "Siemens."

" " p. 307, *after line 31*, *add* "The Author desires to acknowledge the assistance he has received in compiling these notes from Mr. William Clark, of Messrs. Head, Wrightson & Co., Limited, whois the designer and patentee of the hydraulic machinery mentioned in the Paper."

" " p. 348, line 23, *after* "Royal Medal" *add* "in 1857, and the Copley Medal."

" " p. 389, " 31, *for* "1898" *read* "vol. i. 1899."

" " p. 399, " 10, *for* "carbonic oxide" *read* "carbonic acid."

" " p. 546, " 7, *for* "160 millimetres" *read* "160 mils"; *for* "2·625 millimetres" *read* "2·625 inches."

THE

INSTITUTION

OF

CIVIL ENGINEERS.

SESSION 1899–1900.—PART II.

Sect. I.—MINUTES OF PROCEEDINGS.

9 January, 1900.

CHARLES HAWKSLEY, Vice-President, in the Chair.

It was announced that the Associate Members hereunder mentioned had been transferred to the class of

Members.

Howard Brunlees.
George Cunningham Buchanan.
Dugald Clerk.
George Parnall Culverwell, B.A. (*Dubl.*)
Brodie Haldane Henderson.
Edwin James Lovegrove.
Isaac Shepherd McKie.
Thomas Lodwick Miller.
Edward Wyndham Monkhouse, M.A. (*Cantab.*)
Charles Butterworth Newton.
Martin Fenn Roberts.
Robert Julian Scott.
Richard Sholto Strachey.
James Thompson, B.E. (*Royal.*)
Lawrence Fletcher White.
Charles Henry Wordingham.

And that the following Candidates had been admitted as

Students.

Charles Antony Ablett.
Frank Drew Arundel.
Arthur William Elworthy.
Oscar Eugster.
Cecil Arthur Fowler, B.A., B.A.I. (*Dubl.*)
Vincent Joseph Martin, B.Sc. (*Victoria.*)
Richard Cecil Moss.
Richard Francis O'Connor, B.A., B.E. (*Royal.*)
Helmuth Pendennis Peyton.
James Douglas Kendall Restler.
Samuel Coley Rhodes.
William McGregor Ross, B.A., B.E. (*Royal*), B.Sc. (*Victoria.*)
Mom Rajawong Saiyut, B.A. (*Cantab.*)
Percy John Henry Unna.
Charles Weekley, B.A. (*Cantab.*)
George Wyatt.

The Candidates balloted for and duly elected were: as

Members.

Frederick William Bidder.
John Patrick O'Donnell.
Matthew William Parrington.
John Bonsall Porter.
Bensley Thornhill.

Associate Members.

MATTHEW ATKINSON ADAM, B.Sc. (*Glas.*)
EDWIN THOMAS BEARD.
ROBERT BICKERDIKE, Jun., Ma.E. (*McGill.*)
THOMAS COOKSON.
JONATHAN ROBERTS DAVIDSON, M.Sc. (*Victoria*), Stud. Inst. C.E.
JAMES DEAS.
WILFRID JOSEPH DILLEY, B.Sc. (*Edin.*), Stud. Inst. C.E.
WILLIAM HENRY ELCE.
WALTER ERAUT, Stud. Inst. C.E.
PATRICK HAMILTON, B.Sc. (*Glas.*)
HERBERT EDWARD HYDE HARRISON, Stud. Inst. C.E.
ELLICE MARTIN HORSBURGH, M.A., B.Sc. (*Edin.*)
ROBERT HENRY KING, B.A.I. (*Dubl.*)
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RALPH CLASSON PORTER, M.Sc. (*Victoria*)
NEVILLE ROOTS.
EDWARD GOWER STANLEY.
EDWARD HUME TOWNSEND, B.A.I. (*Dubl.*)
WILLIAM MONTGOMERY WALKER, B.E. (*Royal.*)

Associate.

GORDON RISLEY HEARN, *Lieut. R.E.*

(*Paper No. 3167.*)

"The Purification of Water after its Use in Manufactories."

By REGINALD ARTHUR TATTON, M. Inst. C.E.

DURING the last few years a large amount of work has been carried out for preventing pollution of the rivers of Lancashire, Cheshire, Yorkshire and other counties, as the result of pressure brought to bear on local authorities and manufacturers by the Rivers Boards constituted under Section 14 of the Local Government Act of 1888. Until this Act was passed the Rivers Pollution Prevention Act of 1876 had been little enforced, the reason being that an authority, in order to obtain a conviction against an offender on the river above and outside its own district, had to prove specific pollution by that offender within its district; this, in the highly polluted condition of the rivers, was as a rule impossible. Under the new Act a Board can be formed, by order of the Local Government Board, with power to deal with a large area, and to treat alike all offenders within that area. Two Boards have been formed in Lancashire and Cheshire, the Mersey and Irwell Joint Committee, which deals with the Rivers Mersey and Irwell and their tributaries above Warrington; and the Ribble Joint Committee, which deals with the watershed of the Ribble. In Yorkshire a Board has been formed to deal with the rivers of the West Riding. The formation of the Mersey and Irwell Joint Committee, of which the Author has acted as engineer since it was constituted in 1891, was the outcome of a general feeling in Lancashire and Cheshire that the polluted condition of the rivers was a disgrace and a nuisance, and that it was scarcely possible to

improve them under the then existing means for enforcing the Rivers Pollution Prevention Act. The construction of the Manchester Ship Canal, in which the waters of the Irwell were impounded for several days or even weeks in dry weather, rendered the improvement of the rivers a matter of urgency; public meetings were held and application was made by the County Councils of Lancashire and Cheshire to the Local Government Board. A local inquiry was accordingly held at Manchester in December, 1890, and was attended by representatives of the different counties, county boroughs, and other authorities within the area, and also by representatives of the manufacturers. The manufacturers strongly supported the application, and their views were expressed in the following words:—"The manufacturers say that without co-operation between the different bodies and the manufacturers no real improvement would be effected in the rivers. They also submit that individual cases ought not to be taken indiscriminately, or dealt with separately, without some assurance being given that others in the district in competition would be treated on the same principle." The application was granted, and the joint committee was constituted; it is composed of twenty-four members representing the County Councils of Lancashire and Cheshire, and the County Boroughs of Bolton, Bury, Manchester, Oldham, Rochdale, Salford and Stockport.

POPULATION AND RATEABLE VALUE OF DISTRICT.

——	Population.	Rateable Value.		
		£	s.	d.
Seven county boroughs	1,179,331	5,214,252	5	0
Eleven non-county boroughs	294,677	974,411	13	3
Sixty-two urban district councils	639,620	2,674,721	0	1
Ten rural district councils	122,313	867,623	8	0
	2,235,941	9,731,008	6	4

NUMBER OF FACTORIES DISCHARGING DIRECT INTO THE STREAMS, AND POPULATION ON EACH OF THE MAIN RIVERS.

——	Number of Factories.	Population.
Rivers Irwell and Roach	281	1,015,602
River Irk	43	308,786
River Medlock	21	273,550
River Mersey	68	638,003
	413	2,235,941

The early efforts of the joint committee were directed chiefly towards the prevention of pollution by solids, and considerable advance was made; a survey was also undertaken of all the sources of pollution by sewage and trade-waste. It was, however, soon found that the Rivers Pollution Prevention Act of 1876 was in many ways unsatisfactory and difficult of application, and it was resolved to apply to Parliament for further powers. The Bill was opposed by certain of the boroughs and local authorities, but was supported by manufacturers, who from the first expressed the opinion that they would derive benefit from the rivers being improved, and who have as a rule shown great willingness to co-operate with the committee. The Bill was passed and received the royal assent in 1892. During this time the matter was brought before the manufacturers by means of conferences and personal visits to the various works, so that when more active steps were taken later, they had had ample time to make inquiries and to decide on the means they should adopt for the treatment of their waste waters. To this gradual action on the part of the joint committee is no doubt chiefly due the success which has attended their action and the small amount of friction which has been caused.

The following Table gives the number of manufactories in each industry where, in consequence of the polluting character of the waste waters, purification-works are necessary. The respective columns A, B, C, D, give approximately their positions as regards efficiency of treatment.

Class of Pollution.	A. Efficient Works.	B. Works Constructed but not Efficient.	C. Works being Constructed.	D. No Treatment adopted.	Total.
Print-works	31	12	..	..	43
Dye-works	72	29	1	2	104
Bleach-works	44	17	..	2	63
Waste-bleach works	4	6	..	..	10
Paper-works	15	8	..	..	23
Paper-stainers	2	1	..	..	3
Tanners and leather-dressers	6	3	..	..	9
Fellmongers	1	5	..	..	6
Woollen-trades	46	21	..	..	67
Silk-trades	1	2	..	4	7
Slack-washing	8	3	..	..	11
Soap-works	1	4	..	..	5
Stone-polishers	3	3	..	..	6
Chemical-works	10	2	..	..	12
Breweries	3	6	..	3	12
Unclassified	7	22	..	3	32
Total	254	144	1	14	413

The division line between column A and B must necessarily be an uncertain one, and the standard of efficiency is based on a comparison with works in the same industry; but generally, the works in column A are capable, if properly managed, of turning out a satisfactory effluent, whilst those in column B, although intercepting the bulk of the solids, cannot be considered efficient. Amongst the latter are included many works where the available space was too limited to allow of efficient works being constructed.

The progress since 1893 is as follows :—

——	Oct. 1893.	Jan. 1898.
Works with efficient purification-plant	45	254
Works with plant constructed but not efficient.	77	144
Works being constructed	77	1
No treatment adopted	191	14
	390	413

Besides the factories included in these Tables about two hundred and fifty drain into public sewers, and the waste waters are dealt with by local authorities.

The Rivers Pollution Prevention Acts require that "the best practicable and reasonably available means" shall be adopted, and therefore more complete and efficient works can be required when the factory is situated in the country, with plenty of vacant land around, than when it is surrounded by buildings with little or no land on which to construct works. Of the works which have been selected for description two are situated where ample space could be obtained, and the third is an instance of the necessity of utilizing a restricted area of available ground. During the last few years various improved methods have been introduced for treating trade-waste by mechanical filtration after precipitation: some of these arrangements require little space, are easily cleansed, and at any rate remove the suspended solids: and they may be found very useful in cases where space for larger works cannot be obtained.

Bleach, Dye and Finishing Works of Messrs. R. Clay & Sons, Cheadle, Cheshire.

The processes carried on at these works are those of ordinary bleaching, dyeing, and finishing. Logwood and aniline dyes with mordants are used, and the waste waters consist of the contents of the exhausted dye-becks and wash-waters from the dyeing

department and of the contents of the kiers and wash-waters of the bleaching department; they ordinarily amount to 300,000 gallons per day, but when there is a press of work and the bleachcroft is kept working all night, to 500,000 gallons. The whole of this waste is treated. It is collected in a chamber on the north side of the brook, Fig. 1, Plate 1, and flows thence by a trough and pipes to the chamber A, where milk of lime is added by means of a trough and mixer, B; from this chamber the water flows through 18-inch pipes to the inlet-channel, in which a screen is fixed at C, and thence to precipitation-tank No. 1. Blocks of "aluminoferric"[1] are placed in the channel near the screen to assist precipitation. Where lime is used together with another precipitant, it is important that it should be allowed to thoroughly mix with the water before the other precipitant is added. Tank No. 1 is allowed to fill, and then the water passes by an overflow, D, into tank No. 2, and thence by an overflow, E, into tank No. 3. A large amount of sludge is collected in this series of tanks, so that when the water reaches the pumps which lift it to the high-level tanks Nos. 5, 6, 7, it has been freed from a portion of its suspended solids. When No. 3 tank is nearly full, the engines working the centrifugal pumps in the engine-house are started, and the top water is drawn from the tanks through 8-inch pipes to the engine-house and is forced along an 8-inch rising main to the inlet-channel of the high-level precipitation-tanks, where aluminoferric is again added as a precipitant. From the inlet-channel the water flows into the tanks Nos. 5, 6 and 7, which are used in rotation. Each of these tanks has a capacity of 90,000 gallons and takes about 3 hours to fill; 5 hours or 6 hours are allowed for settlement. When clear, the water is drawn off by means of the automatic floating outlets, F, to the filter-beds, which are composed of 6 inches of fine ashes and 12 inches of rough clinkers, with 4-inch tile-drains below, leading into the 15-inch outlet-main, which discharges through an outlet-chamber into the brook; the effluent water is clear, and of a pale straw-colour which is imperceptible in the brook a few yards

[1] The following analysis of "Aluminoferric" is furnished by Messrs. Peter Spence & Sons:—

	Per cent.
Al_2O_3	14·0
Fe_2O_3	0·6
Free SO_3	0·4
Combined SO_3	34·1
Total insoluble	0·1
Water	50·5

below the outlet. The sludge from the high-level tanks is removed after each filling, and is discharged by 9-inch earthenware pipes to tank No. 4, which is kept as a sludge-tank for the high-level precipitation-tanks. At the end of each week the water in tanks Nos. 1, 2 and 3, is allowed to settle for about 5 hours, and is then drawn off by floating arms to filter-bed No. 1, through which it passes to the outlet-chamber. The sludge from tanks Nos. 1, 2, 3 and 4, is discharged by valves, and 12-inch pipes into a well, H, 16 feet deep, from which it is pumped by a centrifugal pump, worked by a gas-engine, into an overhead trough to the sludge-tank; the top water from this tank is drawn off into the main inlet-channel. The sludge from the tank is drawn off by pipes into the sludge-receivers in the press-house, and is pumped into sludge-presses fixed on the first floor. The solid matter from the presses falls through shoots into wagons, and is removed to a tip; the liquid from the presses is returned to the inlet-chamber for further treatment. Previous to the erection of the presses, the sludge was pumped to the west side of the brook and was deposited in a lagoon, but the quantity was so great that presses became a necessity. The machinery for dealing with the sludge consists of an engine, a 6-inch single-acting air-compressor, worked at 100 lbs. pressure per square inch, and two presses, each containing twenty-four 30-inch plates. The presses perform fourteen pressings daily, but when the tanks are worked at night it is necessary to work the presses also, and then twenty pressings are made. The sludge presses well, and it is not necessary to add lime; each pressing weighs 12 cwt. (of cake) and requires between 20 minutes and 1¼ hour; ¾ of an hour may be taken as the average time. Two men are sufficient to perform the whole of the work in connection with the tanks, engines and sludge-pressing machinery, with two additional men when working at night. Cleaning the filters is an extra item, though not of large amount; but before long it will be necessary to cart away the pressed cake to a field some distance from the works; £50 a year has been assessed as the probable cost of this.

The average composition of sludge as it passes to the presses is:

	Per cent.
Solid matter	4·37
Water	95·63

The composition of the pressed cake taken on an average of twelve pressings is:

	Per cent
Solid matter	28·55
Water	71·45

The cost of the works was as follows:—

	£
Tanks and filters with all connections, pipes and drains inside the factory	4,740
Two presses, 6-inch air-compressor, and lime-mixer	560
Engine	200
House containing engine, presses, etc.	500
	6,000

The annual cost of working, on the basis that night-work is carried on during 6 months of the year, is as follows:—

	£	s.	d.
Precipitant—			
Lime and aluminoferric	120	0	0
Wages	240	0	0
Disposal of sludge	50	0	0
Renewal of filter-beds	20	0	0
Cost of steam	100	0	0
	530	0	0

The cost of steam is difficult to estimate, but will probably amount to the sum noted. Two hundred and ten men are employed in the factory.

Woollen-Manufacturing and Dye-Works of Messrs. Kelsall and Kemp, Norden, near Rochdale.

The manufacturing processes carried on at these works comprise piece-scouring, manufacturing, dyeing, and finishing. The purification-works present somewhat peculiar features, not only by reason of the foulness of the waste waters with which they are designed to deal, but also from the difficulty of obtaining sufficient land on which to erect the necessary works. If the works had been constructed in their entirety at the outset, possibly somewhat better arrangements might have been made; but they have developed as the necessity for better treatment of the water arose, and at present, although somewhat complicated, are certainly very effective.

Treatment of Soapy Water from the Scouring and Finishing Departments.—The water from the washing-troughs in the mill is collected, and is delivered by an earthenware pipe into the chamber A, Fig. 4, Plate 1, where it passes through a fine copper sieve which collects the flocks or small particles of wool which are carried away in the water. The sieve is cleaned by a revolving brush, and the flocks being of value are collected. Details of this arrangement are given in Figs. 8. From the chamber A the

water flows through 8-inch earthenware pipes to the pumping-chamber, where two "aqua-thruster" pumps force it through a 4-inch rising-main to the box C, where it falls on a water-wheel which works a lime-mixer in an adjacent box. The milk of lime is discharged from this box into the trough, through which the soapy water flows from C to the settling-tanks for treatment; a solution of ferric chloride is also run into the trough from the precipitant-tank at a point about 12 feet distant from where the lime is added. The series of settling-tanks Nos. 1, 2 and 3, is so served by troughs and overflows that any two tanks can be used whilst the third is being cleaned. From these tanks the water flows through a pipe and trough to further settling-tanks, Nos. 4 and 5, and thence on to the filter-beds Nos. 1 and 2, the overflows from each tank being provided with scum-boards; the water is distributed on the filter-beds by a perforated trough. The filters, which are used alternately, are composed of fine ashes with drain-pipes at the bottom, and the water passes through them into the 6-inch effluent-pipes and a trough fixed round the sides of the sludge-tanks, thence through the chamber L by a series of troughs and channels to the stream. When two tanks of the series 1, 2 and 3 have been in use for 1 week, the first tank is shut off and the third is brought into use. The top-water from the disused tank is then drawn off, after settlement, by the floating outlet-valve into the inlet-chamber of the dye-water settling-tanks, to be described later. The sludge in the tank is then well mixed with sulphuric acid, and is drawn off by the sludge-valve at the west end of the tank into the sludge-trough, and thence into sludge-filters made of cocoanut-matting. These filters are shown in section in Fig. 7. The action of the acid on the sludge is to split up the insoluble lime and iron soap, setting free fatty acid and neutralizing the lime and iron: the sludge will not press with free lime in it. The surplus acid drains through the matting-filters into the collecting area below and the sump-well O, whence it is pumped by an "aqua-thruster" into the precipitant-tank for use over again. The sludge from the matting-filters is taken to the press-house, where it is pressed and the oil from it is recovered; the solid refuse which remains is burnt. The oil is then further refined by distilling and pressing, and the stearine and oil which are produced are sold.

Treatment of the Dye-water.—The water from the dye-house is conducted by an earthenware pipe to a chamber A, Fig. 4, passing under the sieve which collects the flocks from the soapy water,

from which it is kept separate, but with a similar arrangement for collecting the flocks contained in the dye-water; thence it flows through earthenware pipes to the inlet-channel of the settling-tanks Nos. 6, 7, 8, 9 and 10 (where it is joined by the water from whichever of the tanks 1, 2, or 3 is being drawn off for cleaning) over the trough V and successively through the tanks, which are used on the continuous system—scum-boards being fixed at the outlet from No. 6 tank and also from the outlet to No. 10, where the water flows on to filter-beds Nos. 4 and 5; these beds are surcharged, the water flowing from them by a vertical outlet on to either of the fine-cinder filters 6, 7, 8 and 9: the water finally flows into the effluent-channel to the stream. All the fine filters, 1, 2, 3, 6, 7, 8 and 9 are composed of clinkers at the bottom, covered by a layer of coarse cinders, with an 18-inch layer of very fine ashes on the top. The sludge from settling-tanks 6, 7, 8, 9 and 10 is drawn off into the sludge-tank No. 3, from which it is pumped into sludge-tanks Nos. 1 and 2 by an "aqua-thruster," and is afterwards carted to a tip. When filters Nos. 4 and 5 require cleaning, the water can be drawn off by earthenware pipes which discharge into the effluent-channel. The total volume of water used amounts to 180,000 gallons per day. The number of hands employed is ninety. The analysis of the untreated waste from the dye-house, Appendix, Table I, shows it is free from suspended solids. This is probably due to the fact that woollen material absorbs the dye more readily than cotton goods and therefore leaves less solid matter in the dye-becks, and also that in this mill alizarine dyes only are used, which contain very little solid in suspension; the solids are also reduced by using the bichromate of potash with which the wool is mordanted preparatory to dyeing, as boiler-composition. For this purpose a tank has been made under the floor of the dye-house into which this liquor is run after the wool has been mordanted, thence it is pumped into the boilers and used in them for the prevention of scale. Since this plan has been adopted no other boiler-composition has been found necessary, and the valves have lasted better than previously.

This example shows the most complete and elaborate arrangement to be found in the watershed for dealing with this kind of waste, but there are a large number of woollen-mills where simpler works have been constructed which give excellent results; these consist of sap-tanks, precipitation-tanks, and filter-beds. In the sap-tanks the water from the scouring processes, which contains most of the grease, is received and treated with acid, and the grease is recovered. This process has been practised in a more or

less perfect form for many years, especially when the value of soap allowed it to be done with profit. The clear effluent water from the sap-tanks then joins the rest of the waste water, and the whole is treated with a precipitant and allowed to settle in the precipitation-tanks, the clear effluent water being subsequently filtered through cinders or other fine material.

The capital expenditure on these works is as follows:—

	£	s.	d.
Tanks and filters, pumps, etc.	1,250	0	0
Magma-pressing	380	0	0
Distilling and stearine-pressing	340	0	0
	1,970	0	0

The cost of treatment during the year 1898 was as follows:—

	£	s.	d.	£	s.	d.
Ferric chloride				24	3	0
Oil of vitriol				69	3	9
Lime				19	18	10
Bags (for pressing)				26	11	2
Sawdust				1	19	0
Plumbing repairs				10	12	7
Repairs to pumps, valves, etc.				17	9	2
India-rubber bungs, etc.				5	15	10
Test-tubes and chemicals					12	4
Magma-press plates				7	19	5
Sundries				7	8	8
Wages				346	13	5
Coal for distilling and steam for pumps				50	0	0
Gross cost				588	7	2
Deduct revenue—						
Sale of recovered oil and stearine	336	11	0			
Saving of boiler-composition	52	0	0			
				388	11	0
Net cost				199	16	2

Say £200 per annum.

Calico-Printing, Dye and Bleach Works of Messrs. Sydall Brothers, Limited, Chadkirk.

The processes carried on at these works, in which one hundred and ninety-five hands are employed, comprise those of an ordinary calico-print works, and the pollution is caused by alizarine and aniline dyes, logwood and other wood-extracts, soap, starch, fustic, soda, bleaching powder, etc. The whole of the trade-waste, including the wash-waters, is collected in a wooden trough which is fixed along the west wall of the works, and intercepts the water from the various outlets which formerly

discharged direct into the river. This trough discharges into the small chamber A, Fig. 9, Plate 1, and the water passes under division walls into the chambers C and E and over a wall into the chamber G, where an "aqua-thruster" pump is fixed which forces it through a 12-inch iron pipe to the settling-tank: the pump is regulated by a float on the surface of the water, and, as the water rises or falls in the chamber, the float, which is connected by an arrangement of levers to the steam-supply which works the pump, increases or diminishes the supply, thus causing the pumps to work quickly or slowly according as the quantity of water from the works varies. This chamber or detritus-tank intercepts a considerable quantity of solid matter, and is cleaned out every week. The supply-pipe from the pumps terminates in the chamber H, whence the water flows under the division-wall J and over the wall L into the settling-tank, and thence by sluices at M into either of the two precipitation-tanks. A considerable amount of sludge is collected in the detritus-tank, thus relieving the pump, and also in the settling-tank, which is filled to a depth of about 4 feet before the water flows into the precipitation-tanks. Blocks of alumino-ferric are placed against the screen at M to assist precipitation. Each precipitation-tank holds about 178,000 gallons, takes 2½ days to fill, and is allowed 48 hours to settle, during which time the water is diverted into the other tank. After settlement the water is drawn from the tank by a floating outlet-valve into an 8-inch pipe, and thence through 4-inch distributing-pipes to the filter-beds Nos. 1 and 2 in succession, the water thus undergoing a double filtration; the outlet-pipes to No. 1 filter are turned up vertically at their outlet end (Fig. 10) and are brought up to the level of the surface of the filter, so that the filter when in use is fully charged; a division wall in the outlet-chamber, over which the water has to pass, causes No. 2 filter also to be fully charged before any water flows from it; this method of using the filters no doubt somewhat reduces the quantity of air admitted into them, but affords a ready means of utilizing the whole of the bed, and also of preventing the water from flowing through them too quickly. The filters are composed of 12 inches of stones, 12 inches of clinkers, and 18 inches of fine ashes on the top. The sloping sides of the tanks and filters and the bottoms of the tanks are merely pitched with 3-inch brickwork set dry. The foundation is of good clay. The sludge collected in the settling-tank is cleaned out every 3 months through a sludge-valve at the south end, into the sludge-tank, care being taken that sludge only is

allowed to pass, the sludge from H being swept through openings in the walls J and L into the settling-tank. The sludge from the precipitation-tanks, after the top water has been drawn off, is also discharged by 9-inch pipes into the sludge-tank, whence it is lifted by a bucket-pump into a wooden trough leading to the sludge-drying area. The sludge when dry is spread on a grass field adjoining. The precipitation-tanks are cleaned of sludge after each filling. If the filter-beds require cleaning out, the water can be drawn from them entirely by means of a valve at P for No. 1 bed, and a valve in the outlet-chamber for No. 2 bed. The analysis of the water after it leaves the precipitation-tanks, and of the filtered effluent, shows that, contrary to the experience at Clay's dye-works, the filters make a great improvement (Tables II–IV, Appendix); this is probably due to the fact that more soap and size is used at a print-works than at a dye-works, a considerable amount of those substances being in solution can only be removed by filtration.

The total cost of these works, including the tanks, filters, pump and piping complete, was £650.

ANNUAL COST OF MAINTENANCE.

	£	s.	d.
Precipitant	56	0	0
Cost of steam	30	0	0
Labour, including extra labour required when tanks are emptied of sludge, but not including carting sludge on to land	63	0	0
	149	0	0

The recovery of waste products has been attended with considerable success at one print-works in the watershed. About 1,000,000 gallons of water are used in the works daily, of which about one-half requires treatment; the remainder, being clean wash-water, is allowed to flow directly into the stream. The general purification works consist of precipitation-tanks and filters, but the waters containing soap, logwood, and indigo are subjected to preliminary treatment before being passed on to these tanks, the solids in them being recovered. The soap-liquor is precipitated in a tank with lime and aluminoferric, which precipitates the greasy matter; this is pumped into a filter-press, and the cake produced is boiled by means of steam and the grease is recovered; the acid and alum which separate from the grease in the process of boiling are drawn off and used again to precipitate the next tankful of soap-liquor. The grease is worth at least £7 per ton, and it is estimated that at £4 10*s*. it pays the whole of the working-expenses

of recovery, including wages and chemicals; the quantity produced is between 15 tons and 20 tons a year.

The separate recovery of indigo is generally adopted now at works where any considerable quantity is used, and is a very remunerative process—the value of the products recovered at these works amounting to about £1,200 a year on a total consumption of about £4,000 worth of the raw material. The indigo is recovered from the solid which settles at the bottom of the dye-vats and also from the wash-water, through which the pieces are passed after being dyed. The wash-waters are first precipitated in tanks under the floor of the works with aluminoferric and caustic soda, the top water is drawn off by means of a valve with a floating arm, and the solids, together with those from the dye-vats, are pumped up into a tank where they are treated chemically; this separates the pure indigo, which is used again in the dye-house.

The separate treatment of the logwood-liquor has for its object not the recovery of the waste products, which are, as far as is known as present, valueless, but the simplification of the subsequent treatment in the general precipitation-tanks, the logwood-liquor being difficult to treat and containing a large amount of solid matter, owing to the fact that the ground logwood is put direct into the dye-vats. The plan has been found of great assistance at these works and is well worth adoption. The treatment consists of precipitation with lime and aluminoferric in a tank into which the liquor from the dye-vats and the wash-waters flow; after precipitation the top water is drawn off and the solids are pumped into a vertical cylinder where as much of the moisture as possible is allowed to drain off. The residue is burnt; it has been tried as a manure but does more harm than good, producing fungus. The remainder of the polluting water from the works is collected in a culvert, into which also the partially-treated water from each of the three recovery-plants flows, and passes forward to the general precipitation-tanks and filters; the tanks have a capacity of 413,000 gallons and the filters cover an area of 2,200 square yards. Aluminoferric and milk of lime are added at points in the culvert about 20 yards apart. The accumulation of solids in the tanks is not great and the surface of the filters requires to be renewed only once in 4 months. In connection with the filters, the interesting fact has been noticed, that the surface lasts longer without requiring renewal after the filter has been in use some time than when it is entirely new. This seems to suggest that a biological action establishes itself, as in a sewage-filter. The cost of the precipitation-tanks and filters was £1,500, and the annual cost of maintenance,

including labour and precipitants, is £60; this does not include the cost or the maintenance of the three recovery-plants, which, however, as pointed out, pay for themselves with a good profit.

Considerable saving is also effected in a print-works, as a result of the necessity of preventing the pollution of rivers, by the reduction of the quantity of dyeing materials and starch used, or rather wasted in the works. A large amount of starch of the finest quality is used to form the body of the colours used in printing, and formerly, when the drains of the colour-shop were connected with the river, if a mixing of colour was not correct it was sent down the drain and the principal was ignorant of it; now the drains from the colour-shop and starch-places are closed, and a spoiled mixing has to be taken to the tip, where the errors of the mixer are brought to light.

Conclusion.

The works described above may be taken as typical examples of those required for the treatment of the various kinds of trade-waste, but a few notes as to special arrangements which are advisable in certain cases are appended.

Bleach-Works.—The polluting waters from a bleach-works consist of the water from the kiers, and from the bleach- and acid-tanks, and the wash-waters from all except the final processes. One of the most polluting liquids is the water drawn from the kiers in which the pieces of cloth are boiled; it is strongly alkaline and alone is difficult to treat. At many works it is the custom to run off the kiers, perhaps eight or ten in number, in the morning within a short period of time, with the result that this strong liquor does not have a chance of being mixed with the washing and less polluting waters. This difficulty may be overcome by discharging the kier-water into a separate tank, from which it may be drawn off gradually and mixed with the washing waters as they flow to the precipitation-tanks, when no difficulty will be found with its treatment. The final washing waters may, as a rule, be admitted into the streams without treatment, but it is often found more convenient to allow them to flow to the tanks than to lay down a separate system of drains. Example No. 3 would be suitable for a bleach-works, therefore no separate example has been given. A process has lately been introduced at one bleach-works for reducing the alkalinity in the water by discharging carbonic-acid gas into the tanks; the gas is produced by means of a coke-furnace, from which it is taken to the tanks in pipes.

Paper-Works.—The materials used in the manufacture of paper

vary so widely at different mills that it is impossible to describe a typical purification-works that would suit all cases. If esparto grass or straw is used, the strong caustic liquor from the boiling of these materials must be evaporated and the soda-ash must be recovered; whether this is profitable or not depends upon the price of caustic soda and whether the quantity of soda used in the works is sufficient to keep an evaporator and incinerator working; but in any case there will be some return for the outlay, and the liquor is of such a polluting character that its treatment is necessary. The wash-waters, which should be economized inside the mill by using them over and over again as much as possible, may be treated by precipitation and filtration in works similar to example No. 3; and this example is also applicable to mills in which rags, hemp, etc., are used, the polluting water in such cases being from the washing, boiling and bleaching of these materials. The recommendation made with regard to the kier-waters from bleach-works applies also to the water in which the rags are boiled at paper-works. The introduction of wood-pulp has entirely changed the preliminary processes of manufacture at some mills, and materially reduced the pollution from them; the whole of the wood-pulp, which is usually prepared abroad, is of value, and any waste of it is loss to the mill, so that a variety of "savealls" (revolving sieves of fine gauze), and settling-tanks have been introduced for the recovery of as much of the pulp as possible.

Tanners' and Fellmongers' Works.—The trade-waste from this class of works should undoubtedly be admitted into the sewers if possible, after preliminary treatment in tanks to remove the grosser solids which might cause silting in the sewers. It is so concentrated and contains such a large amount of organic matter, often in a state of decomposition, that treatment is difficult, whereas if it is mixed with the ordinary sewage of a town, the difficulties with regard to the latter are not materially increased. If separate treatment is necessary, as may be the case in a country district, the works should be constructed to conform to the same rules which apply to sewage-works; the precipitation-tanks should be arranged so that they may be easily and thoroughly cleaned, which will require to be done frequently in warm weather to prevent the sludge decomposing. If suitable land can be obtained on which to run the tank-effluent, it is preferable to artificial filtration; but if the land is of a heavy nature or a sufficient area cannot be obtained, filters must be constructed; double filtration would probably be beneficial.

Breweries.—A large quantity of water is used at breweries for

cooling purposes; this does not require treatment, and should be separated from the polluted water; the latter consists of the washings of barrels, fermenting-vats and cooling-tanks, and is of a very offensive character. It may be treated by precipitation and subsequent filtration. The majority of breweries in the watershed discharge direct into the sewers.

Slack-Washing.—This is a process employed at some collieries for separating small coal, which would otherwise be of little value, from the refuse with which it is mixed when raised from the pit. The water used in the process contains a large amount of solid matter in suspension, which can readily be intercepted in settling-tanks. At some collieries a plant is used from which the solid refuse is removed during the process of washing, so that the water can be used over and over again, and none run to waste.

Chemical Works.—The waste waters from these works are so various that it is impossible to lay down any general rule for their treatment. Each case will require to be taken separately, the composition of the effluent water being ascertained; and if the waste water is found to be inadmissible into either the river or sewers, some means of chemical treatment must be adopted.

From the examples given it will be seen that the cost is variable, and that no general rules for forming an estimate of the cost of treating a given quantity of water can be laid down. The position of the works, the quality of the waste, whether pumping is necessary and to what extent, are all variable factors. In some cases manufacturers have wisely provided a well-designed and well-constructed plant at the outset, thereby reducing the cost of maintenance; whilst others, to their ultimate cost, have adopted a too economical course. In the cost of maintenance interest on capital or depreciation is not included. It has been pointed out that in the case of calico-printers and paper-makers great advances have been made in the last few years in the recovery of valuable materials which used to find their way into the rivers. So far as manufacturing industries are concerned, it seems probable that the rivers will be purified by operations inside rather than outside the works.

The Author gratefully acknowledges the assistance he has received from the owners of the works referred to, and from Mr. Scudder, who has made the chemical report, contained in the Appendix, on samples taken from the three works described.

The Paper is accompanied by six tracings, from which Plate 1 has been prepared.

APPENDIX.

TABLE I.—MESSRS. KELSALL AND KEMP'S WORKS.—CHEMICAL RESULTS EXPRESSED IN GRAINS PER GALLON.

—	Suspended Solids.			Soluble Solids.			Total Solids.			Ammonias.		Oxygen absorbed from $KMnO_4$ in Acid Solution at 60° F.		Transparency as Millimetres seen through.	Alkalinity H_2SO_4 required to neutralise.	Acidity expressed as H_2SO_4.
	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.	Free and Saline.	Albuminoid Ammonia.	3 Minutes' Test.	4 Hours' Test.			
1. Dec. 2, 1898, 10.45 A.M.—Soapy water before treatment[1] . .	22·5	122·5	145·0	77·5	184·0	261·5	100·0	306 5	406·5	0·602	4·410	8·86	41·44	Opaque	3·43	..
2. Dec. 2, 1898, 4 P.M.—After treatment[2]	0	0	0	69·0	11·0	80 0	69 0	11·0	80·0	0·245	0·483	0·23	1·04	280	Neutral	..
Percentage reduction of impurity	..	..	100	11	94	69½	..	..	..	59	89	97½	97½	..	..	..
3. Dec. 2, 1898, 11.30 A.M.—Dye-water before treatment[3] . .	0	0	0	22 5	27·0	49·5	..	..	..	0·231	0·263	0·46	1·07	150	..	14·7
4. Dec. 2, 1898, 4.15 P.M.—After treatment[4]	0	0	0	20·0	8·2	28·5	..	..	..	0·035	0·043	0·18	0·63	210	..	2·94
Percentage reduction of impurity	..	..	..	..	68½	42½	..	..	..	76	83½	61	41	..	..	..
5. Dec. 2, 1898, 4.15 P.M.—General effluent as discharged into stream[4]	0	0	0	42·0	5·0	47 0	..	..	..	0·084	0·095	0·19	0·87	320	..	0·98

[1] A thick greyish-white liquid; froths on shaking; smell of wool-perspiration.
[2] A clear effluent, free from suspended solids; faint smell of wool-perspiration.
[3] A blue-coloured clear effluent, free from suspended matter; no smell.
[4] A clear effluent, free from suspended matter; no smell.

TABLE II.—MESSRS. SYDALL BROTHERS' WORKS.—CHEMICAL RESULTS EXPRESSED IN GRAINS PER GALLON.

Description of Sample.	Date, 1898.	Solids in Suspension.			Solids in Solution.		
		Mineral.	Volatile	Total.	Mineral	Volatile.	Total.
Crude waste from the works as it entered the tanks . . .	Dec. 16, 11 A.M.	4·0	26·0	30·0	29·0	21·5	50·5
Effluent from the settling-tank . .	Dec. 19, 12 noon	..	..	..	41·0	22·5	63·5
Effluent after filtration	Dec. 19, 12.30 P.M.	..	..	..	47·0	19·0	66·0

TABLE III.—MESSRS. SYDALL BROTHERS' WORKS.—CHEMICAL RESULTS EXPRESSED IN GRAINS PER GALLON.

Description.	Date.	Suspended Solids.			Solids in Solution.		
		Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.
Crude waste from the sump under pump	Jan. 30, 1899, 10 A.M.	12·5	27·0	39·5	36·5	20·5	57·0
Tank-effluent passing to the filters. Standing from January 30. . . .	Feb. 1, 1899, 12.20 noon.	5·0	10·0	15·0	45·0	28·5	73·5
Effluent from the filter	Feb. 1, 1899, 1.20 P.M.	1·5	4·0	5·5	55·5	13·5	69·0

TABLE IV.—MESSRS. R. CLAY AND SONS' WORKS.—CHEMICAL RESULTS EXPRESSED IN GRAINS PER GALLON.

Description of Sample.	Date, 1898.	Solids in Suspension.			Solids in Solution.		
		Mineral.	Volatile.	Total.	Mineral.	Volatile.	Total.
Crude waste from the works as it entered the tanks . . .	Dec. 15, 11.30 A.M.	1·0	18·5	19·5	44·5	3·5	48·0
Crude waste from the precipitant-mixing tank	12 noon	31·0	2·0	33·0	97·0	12·0	109·0
Effluent from settling-tank after 3 hours' subsidence.	3 P.M.	..	..	..	96·0	20·0	116·0
Effluent from filter	3.30 P.M.	..	..	..	102·0	18·5	120·5

(*Paper No. 3165.*)

(*Abridged.*)

"Experiments on the Purification of Waste Water from Factories."

By William Oliver Evelyn Meade-King, M. Inst. C.E.

The experiments described in this Paper were made with a view to advance the subject of the treatment of factory waste water, by obtaining a better knowledge of the action of precipitants suitable for use in the cases of the various trades considered. The limited area available for purification-works at many manufactories points to the necessity of rapid treatment, and, especially where organic impurities are extensively present, to the employment of precipitants or astringents which will tend to collect, and carry down by their superior weight, the matter held in suspension.

On the assumption that precipitation followed by filtration is to be resorted to—since, with a few exceptions, neither of these alone is able to yield an effluent fit to turn into a stream—the first thing to be determined is the cheapest and most suitable precipitant, having due regard to efficiency and the particular waste to be dealt with. When it is remembered that glycerine is but a waste product, which for years was allowed to flow away in the sewers, it appears possible that valuable by-products, now unutilized, could be recovered from factory waste water if properly precipitated. As it is sufficient to prevent impurities, solid and otherwise, from finding their way into rivers and streams, no attempt was made to ascertain the composition of the precipitates. The samples of waste water chosen for experiment were obtained from works in the Mersey and Irwell Joint Committee's district, and the Author is indebted to their chief inspector, Mr. R. A. Tatton, M. Inst. C.E., for the samples and for information concerning them in the crude state.

In a report dated February, 1898, Mr. Tatton divides the factories situated on the rivers Irwell, Roach, Irk, Medlock and Mersey, into the following classes:—(1) print-works; (2) dye-

works; (3) bleach-works; (4) waste-bleach works; (5) paper-mills; the works of (6) paper-stainers; (7) tanners and leather-dressers; (8) fellmongers; (9) woollen-trades; (10) silk-trades; (11) coal-slack washers; (12) soapmakers; (13) stone polishers; (14) chemical manufacturers; (15) brewers; (16) unclassified. With two exceptions (Nos. 12 and 13), samples of waste water were obtained from each of the works named, and in addition, samples of sewage were obtained from two places where trades waste water is taken in the sewer. No. 16 was omitted, and the two samples of sewage were labelled 16 and 17. Many experiments were tried with each waste water, but it has been thought desirable to restrict the present Paper to an account of some of the more successful results, which indicate the direction in which trials on a large scale may be reasonably undertaken in various cases as they occur in practice. Wherever it has been possible to obtain the information, the number of hands employed in the factory is given, as well as approximately the discharge of waste water per day.

In describing the filtering process adopted, in all cases where filtering through silicated carbon is mentioned, circular pieces of compressed carbon were employed, about 2 inches in diameter and 2 inches deep. These are very cheap, and can be obtained in nearly any size, and there is nothing to prevent any number of them being used in a filter if their use is desirable.

Experiments.

No. 1.—Print-Works.

In the factory from which this sample of waste water was obtained three hundred hands are employed, and the discharge of waste water per day is stated to be approximately 250,000 gallons. The materials used in the factory include soap, alizarine, logwood-extract, castor-oil, tin, zinc, tan-bark, acetic and wood-acids, caustic soda, bleaching powder, albumen, glue, size, rice-flour, and hydrochloric acid.

The quantity of sample used in each test was about 9 ozs. When it was left standing for a time without any treatment a heavy dark sediment settled down. The sample, on testing with litmus paper, proved to be neutral.

(1) Infusion of oak-bark or gall-nuts, followed by a few drops of salt water, produced immediate precipitation on addition of the salt water. Filtered through silicated carbon, the effluent was

green. Alum and salt water produced further precipitation and a clear effluent.

(2) Solution of washing-soda, followed by salt water, produced a reddish-brown precipitate on stirring. Filtration through silicated carbon gave a colourless effluent, free from smell.

The inference drawn from the experiments is that a waste water from print-works, similar in nature to the sample under consideration, can be precipitated quickly by the simplest ingredients, namely, water in which oak-leaves, oak-bark, or oak gall-nuts, have been boiled, or by a solution of common washing-soda. Either precipitant appears to be greatly aided by the addition of a small quantity of salt water, and the stirring of the whole once or twice after mixing. The exact proportion must be left to be decided according to the size of the works, and the relative impurity and volume of the waste water. The tank-effluent requires filtering as all tank-effluents do, and if the silicated carbon is found too slow in practice, a filter might be composed of granulated charcoal, coke-breeze, coal-dust, and fine gravel, in layers of about 1 foot each.

No. 2.—Dye-Works.

The sample here dealt with was obtained from a factory employing two hundred hands. The discharge of waste water per day is said to be approximately 90,000 gallons. The materials used in the works are logwood, sulphate of iron, acetate of iron, copper, bichromate of potash, and aniline colours. The waste water is stated to contain china-clay, spent logwood, and fatty substances from grey cloth. This proved a very refractory waste, doubtless owing to the presence of the aniline dyes. The sample was proved by litmus paper to be neutral. The following are the results obtained by addition of the solutions mentioned, to separate portions of the sample:—

(1) Infusion of oak-bark threw down a heavy dark precipitate leaving a clear filtrate; but the process was slow.

(2) Solution of iron-alum [1] with a few drops of ammonia and salt water gave a thick white curdy precipitate. The effluent was of a rusty-iron colour which disappeared on filtration through granulated charcoal.

The conclusion was that for the treatment of waste water from dye-works, iron-alum, used in proportion suitable to the volume of waste to be dealt with, should be used as a precipitant,

[1] Ferric ammonium sulphate.

with sufficient ammonia to neutralize the waste, followed by an addition of salt water. The precipitating-tanks should each be of sufficient capacity to hold not less than 3 hours' flow; and the effluent drawn from the tanks should be filtered, preferably through granulated charcoal and fine gravel in succession.

No. 3.—Bleach-Works.

This sample of waste was obtained from a factory employing two hundred and eighty hands. Approximately 300,000 gallons of waste water are discharged per day. The factory supplying the sample uses bleaching powder, soda-ash, hydrochloric and sulphuric acids, resin and china-clay. The waste is stated to contain spent starch, china-clay, chlorine, and fatty substances from grey cloth and lint. The waste water was proved by litmus paper to be strongly acid, as might be expected from the chemicals used, but had the sample been taken early in the day, when the earlier processes were in progress, it would have been alkaline, as the acids are used for "souring," which is one of the later processes.

To 5,000 grains of waste water 100 grains of solution of iron-alum were added; there was no appreciable effect. To this mixture 100 grains of salt water were added, but still without effect; to this 2 or 3 drops of strong ammonia were added to neutralize the acids (probably during the earlier part of the day the addition of ammonia would be unnecessary). On stirring the mixture briskly once or twice with a glass rod, a stringy and thick precipitate at once formed throughout the whole depth of the liquid, and fell as quickly as it formed, leaving a comparatively clear effluent, which, when filtered through silicated carbon, appeared perfectly clear and colourless and free from smell; and a sample was kept as purified effluent.

The quantities of the precipitants used in this example were in excess of what would be required in practice. The iron-alum used was a solution of about 10 grains to 2,000 grains of water; therefore the 100 grs. of solution used represent about ½ gr. of alum; but it may be safely assumed that this is a case requiring strong measures, and probably 20 grs. of alum to the gallon would be found necessary. An automatic arrangement would be necessary for thoroughly mixing the precipitants with the matter to be precipitated. Two filtering mediums would probably be found sufficient, such as fine gravel followed by silicated carbon; but seeing that the volume of waste water is large (300,000 gallons a day) granulated charcoal might be substituted for the silicated

carbon. The cost of treatment would be considerable, owing in a great measure to the volume to be treated, the alum, on the assumption of its costing £6 a ton, and 20 grs. to the gallon being necessary, would cost about 2*d.* per 1,000 gallons treated, or £2 10*s.* a day, but it remains to be proved whether there are any valuable products in the precipitated matter. The purification-works for such a volume of waste water would have to be correspondingly large.

No. 4.—Waste-Bleach Works.

The process of waste-bleaching consists in the removal from cotton waste, by means of bleaching, of the oil and dirt which it contains when brought from the mills; the waste is boiled with a solution of bleaching powder in kiers, and is then thoroughly washed. The quantity of water used in the process is large, and the total tank-capacity should be considerable. Although in this case only six hands are employed, the discharge of waste water is said to be approximately 60,000 gallons a day. Lime and caustic soda are the principal chemicals used, and the waste water is said to contain spent lime and grease. The sample of waste water obtained and dealt with was a very dirty dark-brown colour, almost black, and it was very thick.

The most successful results obtained were the following:—

(1) Solution of washing-soda, followed by solution of iron-alum, gave a fine precipitate. The effluent, which was dark brown, was filtered through:—

	Depth in Inches.
Manganese dioxide	3
Fine, well-washed coal-dust	4
Small " " coke-breeze	5
Fine " " pea gravel	5

The resulting filtrate was of a very pale yellow colour, and clear. On passing it through silicated carbon only a faint yellow tinge remained; it was then clear and free from smell.

(2) The addition of solution of alum, followed by tannic acid and lime, resulted in a dense precipitate settling slowly. The effluent, treated as in No. 1, gave a satisfactory filtrate, even without passing it through the silicated carbon.

If precipitation were resorted to in such a case as this, the tanks would have to be so arranged as to give ample time for the precipitate to settle, and a number of small tanks would be preferable to one or two larger ones, so that each tank could remain full and absolutely undisturbed for 2 hours at least. If this

were done it would probably be found that subsidence would take place without the addition of a precipitant. The waste is a large volume of water rendered impure by a comparatively small quantity of polluting matters; therefore in this case more could be done by filtration than by precipitation, and the filter-beds should be constructed with a greater area than in most cases. The mediums employed in the experiment are easily and cheaply obtained, so that practically little but the first cost of construction would have to be considered.

No. 5.—Paper-Mills.

At the factory supplying this sample of waste, paper is made from more than one hundred different materials, but it is sufficient to state that it is made from vegetable matter, the principal ingredients being rags and wood-fibre. The sample of waste received, when well shaken up, was very thick and of a dirty-white colour.

To about 1 pint, a very small quantity of solution of iron-alum was added; the result, without any further action being taken, was practically instantaneous; a thick, curdy, heavy white precipitate formed, and at once settled to the bottom of the glass, leaving a dull grey tank-effluent above. In practice, this effluent could be drawn off by siphon, or it could overflow into channels conducting it from the tank on to the filter; but in this case, in order to obtain as much of the effluent as possible, filter-paper was employed; the effluent thus obtained had a slight smell and was rather dull. It was then filtered through fine pea gravel, then coke, then coal-dust. After passing through each medium the effluent showed an improvement, the smell getting less till it finally disappeared, and after passing through the coal-dust, it appeared to be sufficiently purified to turn into a stream. The sample of purified effluent bottled was taken after the effluent had been filtered through silicated carbon, and it is bright and clear, and free from smell; but this treatment is considered to be unnecessary in practice.

This waste should be very easily and cheaply dealt with. A better precipitant than iron-alum probably could not be found, and its action is so rapid that it is believed a very small quantity, say 5 grs. to the gallon, would suffice. The precipitate is heavy and settles rapidly; therefore the tanks, of which there should never be less than two, need not be abnormally large, and the effluent can be drawn off from the tanks and passed direct on to a filter composed of fine gravel, coke, and coal-dust.

No. 6.—Paper-Staining Works.

In this case the waste was of a rich reddish-brown colour, and proved to be strongly acid.

About 1 lb. of the waste water was treated with solution of iron-alum, salt water, and lime-water, to which was added a few drops of ammonia. The first three ingredients produced no appreciable effect, but the addition of ammonia gave a thick cloudy precipitate which settled at once to the bottom. The precipitate obtained was of a reddish-brown colour; it was separated by means of filter-paper, the filtrate thus obtained being bright and clear, and the colour of pale sherry. This was filtered through, first, manganese dioxide, which appeared to have a very good effect; second, coal-dust; and third, coke-breeze. Each filtrate was paler in colour than the preceding one, and the last appeared good enough to turn into a river; but as an additional purification it was passed through silicated carbon, which produced a perfectly clear colourless effluent.

At first sight this appears to be a difficult and expensive waste to deal with, but it is not so. The iron-alum, salt water, and lime-water are all cheap ingredients, and can be so arranged as to drop into the waste water before this reaches the precipitating tank. An exceedingly small quantity of ammonia is necessary, and mechanical means must be taken to stir the liquid after flowing into the tank, but care must be taken that it is not overstirred. The filter-bed is simple and needs no further explanation, but if the waste is not of large volume, filtering through silicated carbon as a final stage is undoubtedly beneficial; this process is necessarily slower than other filtering mediums, and in cases of large volumes of waste it would probably have to be dispensed with.

No. 7.—Tannery.

The sample of waste water received from this tannery was of a very dark leather-colour and was most offensive, smelling strongly of sulphuretted hydrogen. The most successful result in this case was obtained by the addition of lime-water, which produced a fine precipitate, leaving a clear dark reddish-brown effluent. On passing through the manganese-dioxide filter it became perfectly clear and colourless, and free from smell.

There is little doubt that lime is the proper precipitant to use in this case, and, as usual, when lime-treatment is adopted, the quantity it is necessary to use is rather in excess of other precipi-

tants; in this case it is recommended that not less than 15 grs. per gallon be used after being thoroughly mixed with water to about the consistency of milk. The tank-capacity in the case of tanneries is of great importance; each tank should hold at least 4 hours' flow, that is to say, if two tanks are employed. For the filtering medium manganese dioxide, as proved by the experiments, is thoroughly efficacious; it not only acts as a cleanser and purifier, but seems to get rid of the objectionable smell.

No. 8.—Fellmongery.

This sample of waste water was perhaps more offensive than the sample obtained from the tannery just described. Fellmongering consists in preparing skins to make leather; the hides are received in all states, some fresh, some salted, and all filthy; they are soaked in water, and various ingredients are used to assist in the cleansing operation, such as borax, brine, sodium sulphide, and other matters. The treatment of fellmongers' waste and of that from tanneries is very similar.

To 10 ozs. of the crude waste, milk of lime was added, as in the case of the tannery-waste; this quickly threw down a precipitate, which appeared comparatively large in quantity, but soft and compressible; the effluent was drawn off and filtered through manganese dioxide, coal, coke, and gravel. The four mediums were 3 inches, 4 inches, 5 inches, and 5 inches, respectively, in depth, and the filtrate was allowed to drop from one medium to the next through a space of about 1 inch in each case; this dropping from one medium to the other has the beneficial effect of causing aëration, and at the same time it helps to keep the filter in good working-order. The effluent obtained after filtration seemed remarkably good; it was perfectly clear, colourless, and free from smell; the remainder was filtered through silicated carbon, but this was unnecessary, the first effluent of which a sample was taken appearing to be quite as good as the second.

Careful treatment is required with such an exceedingly offensive waste as that from fellmongers' works, and it must not be forgotten that in the treatment of skins of some of the rarer animals arsenic is used, and should be provided for if found.

No. 9.—Woollen-Trades.

The waste water experimented on was obtained from a factory employing ninety-two hands, and discharging approximately 75,000 gallons of waste in 24 hours. The chemicals used in the factory are

hydrochloric acid, sulphuric acid, soap and soda-ash, and the waste water is said to contain fatty substances from wool, lime, soap, and spent acid. Grease is recovered from the "suds" at this factory. The following results were obtained with a sample which proved neutral on testing with litmus paper:—

(1) Alum followed by tannic acid threw down a heavy flocculent precipitate, leaving a clear colourless filtrate with a strong smell.

(2) Iron-alum caused a thick scum to form on the surface; addition of ammonia to the liquid siphoned from underneath gave a heavy dark-yellow precipitate; filtration through silicated carbon gave a clear colourless effluent.

This was one of the first samples obtained and experimented on, and the filter which played such an important part in most of the subsequent experiments had not been constructed; nevertheless the fact of one filtration through silicated carbon proving sufficient shows it to be an effluent requiring only ordinary filters. The precipitating-tanks are the most important feature here. The waste should first enter a tank where treatment by iron-alum in a dry powdered state not only precipitates, but causes the scum to rise quickly to the surface, and it should be so arranged that the liquid beneath the scum and above the precipitate can be drawn off into a second tank where ammonia can be added literally by the drop, the liquid in this case being drawn from the top of the tank on to the filter-bed.

No. 10.—Silk-Trades.

The sample of waste water in this case was supplied by silk dye-works, near Macclesfield, employing fifteen hands.

The discharge of waste water per day was not stated. The ingredients used in the factory are stated to be aniline dye, tannic acid, sulphuric acid, gum and soap. The crude waste had a dull, dirty-white appearance and was very thick.

On the addition of lime-water followed by salt water a dark precipitate formed readily. On filtering, the effluent had a faint reddish-yellow tint, but was clear.

Iron-alum, followed by ammonia, and then salt water, produced a heavy black precipitate. Filtration through silicated carbon gave a clear colourless filtrate.

This waste water, in common with all those containing aniline dyes, is a difficult one to deal with.

Lime-water is probably the best clarifier for this waste that could be found, and the addition of a little salt water helps it and hastens the precipitating action.

No. 11.—Coal-Slack Washing.

The coal-mine supplying this sample employs four hundred hands, and the discharge of dirty water is about 50,000 gallons a day. When shaken up, the waste was very thick and almost black.

To about a pint of the crude waste 50 grs. of solution of iron-alum, made by dissolving 100 grs. of the salt in 2,000 grs. of water, was added and stirred. There was no immediate appreciable result. On the addition of 50 grs. of salt water a fine black precipitate instantly formed. The liquid, which proved to be neutral, was siphoned off and had a rather light, dull-grey appearance; it was filtered through 5 inches of coke-breeze followed by 5 inches of fine gravel. It was then colourless and free from smell, and was considered good enough to turn into a river. Filtered through silicated carbon, which, as might be expected, had an excellent effect, the effluent had the appearance of clean filtered water.

This is a very simple and, at the same time, inexpensive waste to deal with. It is quite possible, considering the nature of the works, that if tanks of sufficient capacity were provided, say to hold a day's flow, no precipitant would be necessary; but if artificial precipitation is resorted to, then iron-alum, with the addition of a small quantity of salt water, is all that is required; but it must be agitated or stirred after mixing. Two filtering mediums for the tank-effluent would be sufficient, and these of the simplest character—coke and fine gravel—though of course the effluent could be improved by further filtration if desired.

No. 14.—Chemical Works.

Works of this description embrace a large variety, and it is important to know what that waste contains before putting down works to purify the waste water. On the other hand, there is, of necessity, at least one professional chemist always engaged on the premises, and he should be able to state the system of purification most applicable. At the factory from which the sample of waste water was received two hundred and seventy hands are employed, and the discharge of waste is about 50,000 gallons a day. The materials used are such things as naphthalene, sulphuric and other acids, and iron, and the waste is said to contain oxide of iron, picric acid, naphtha-washings, &c. The waste appeared very thin, that is, there were no solid matters in suspension, and it was practically black.

Several tests were made on small quantities of the waste water in test-tubes. Satisfactory results were obtained in two cases. These were accordingly repeated on a larger scale.

To 10 ozs. of the original waste, 5 grains of lime thoroughly mixed with 200 grains of water were added, followed by 150 grains of salt water and then 2 drops of ammonia. In a very short time a considerable amount of fine white precipitate formed, falling to the bottom, and a dense black precipitate formed in considerable quantity throughout all the liquid in the glass; the addition of the ammonia seemed to increase the precipitate. The latter was separated from the effluent by filter-paper; the liquid filtered readily, and the effluent obtained was of a dark mahogany colour and quite clear. It was siphoned through a glass tube, about $\frac{1}{8}$ inch in diameter so as to deliver it slowly on to a filter of 6 mediums with a space of 1 inch between each:—

1. Manganese dioxide	9 inches deep.
2. " "	3 " "
3. Coal-dust	4 " "
4. Coke-breeze	5 " "
5. Fine gravel	5 " "
6. Silicated carbon	2 " "

After the 5th medium the effluent obtained was of a very pale yellow colour and quite clear, and after the silicated carbon it was perfectly clear and free from smell, with only a very slight tinge of yellow left. When the filter came to be thoroughly washed and cleansed, as it was after every time of using, most of the colouring matter appeared to have been retained in the first 9 inches of manganese dioxide, the quantity in the various mediums becoming less as the bottom one was reached, and the gravel containing very little of it indeed.

To 10 ozs. of waste water were added 250 grains of solution of carbonate of soda; this solution was formed by dissolving $\frac{1}{4}$ oz. of carbonate of soda in 2,000 grains water. To the mixture 250 grains of salt water were added; a very slight precipitate formed, the liquid remaining practically black, and even stirring had no appreciable result; consequently a small quantity of lime-water was added and the mixture stirred again, when instantaneous precipitation took place, but the liquid still proved to be acid. Two drops of ammonia were then added; this had the effect of making it alkaline, and at the same time it seemed to set up a second precipitation, the liquid above the precipitate becoming perfectly clear and of a dark golden-brown colour. This was filtered through silicated carbon, without any

effect whatever. Accordingly the effluent was then filtered through 3 inches of manganese dioxide, 4 inches of coal, 5 inches of coke, and 5 inches of gravel; the effluent then obtained was quite clear but the colour of very pale sherry. Some of this pale effluent was exposed to sunlight and air for 3 or 4 days, but with absolutely no effect.

There is very little doubt that lime is the most suitable agent to use in this case, and it should be used sparingly.

No. 15.—Brewery-Waste.

Brewery-waste, if unmixed with other impurities, is in itself an easy waste to deal with. At the brewery supplying the sample experimented on, about one hundred hands are employed. The discharge per day is not known, but the waste is said to contain spent hops, yeast, and a small quantity of sweetening matter, such as raisins or glucose. The sample had a disagreeable smell, and was somewhat thick. About 1½ lb. of the liquid, after being well shaken up, was treated with a small quantity of solution of iron-alum, the effect being to turn the liquid to a dirty-brown colour. On stirring the mixture briskly for a minute or two, immediate precipitation took place, whilst a slight scum formed on the top. The effluent was separated from the precipitate by filter-paper, and proved to be quite clear and of a very light yellow tint, with a faint smell, such as can be imagined of weak beer. It was filtered through four mediums—

	Depth in Inches.
Manganese dioxide	3
Fine gravel	4
Coke-breeze	5
Well-washed coal-dust	5

As regards the order of the mediums, it is thought desirable in all cases to have the manganese dioxide first, and the order as given above was found to work well in this case, though in other cases it was altered somewhat. Each filtrate was paler in colour than the previous one, and the smell decreased in proportion; the last two filtrates were both colourless, and the last one appeared perfectly clean and pure. The sample that was bottled was a sample of the effluent after being filtered through silicated carbon, and was perfectly clear, colourless, and free from smell; but in practice it is thought the silicated carbon would not be necessary.

Works to purify this waste need only be of a very simple description, but means should be taken to ensure the thorough mixing of the waste and precipitant after the two are deposited

in the tank. The action is rapid, and the tank-capacity need not be excessive: 6 grains or 7 grains of precipitant to each gallon of waste treated would probably be found sufficient. The filter is one of ordinary construction, but a top layer of about 6 inches of manganese dioxide is strongly advocated.

No. 16.—Crude Sewage.

This sample of sewage was obtained from a district with a population of 63,500, and the dry-weather flow of sewage sometimes reaches 3,000,000 gallons in 24 hours, or rather over 40 gallons per head. This large flow is owing to the fact that trade-waters are taken into the sewers, the principal trades of the district being steam laundries. The sewage was of a dirty-brown colour with a bad smell.

1. Infusion of oak-bark, as used in the experiments tried for the treatment of waste water from print-works (No. 1), when added in a test-tube, appeared as if it would have no effect beyond changing the colour, but slight agitation instantly produced a precipitate. When filtered through thin filter-paper, the effluent had a very pale yellow colour.

2. To about 5,500 grains of crude sewage, 5 grains of iron-alum dissolved in 250 grains of water were added; a precipitate instantly began to form, and the addition of 50 grains of salt water hastened it and threw it down. In about 1 minute the liquor was practically clear, though of a golden-brown colour, and there was a heavy dark-brown precipitate, comparatively small in volume. The effluent, after filtration through silicated carbon, was clear, colourless and free from smell.

The only difficulty in dealing with this sewage lies in the fact that it is a very large volume for a comparatively small population. It is easily precipitated with solution of iron-alum and salt water, and almost any artificial filtration, followed by land-filtration on a suitable area, as this is, would turn out a good effluent.

No. 17.—Crude Sewage.

The district supplying this sample of sewage has a population of about 50,000, but owing to the trade-waters being taken into the sewers, the dry-weather flow has been known to reach 7,000,000 gallons in 24 hours, equal to 140 gallons a head per day. This is an unusual case, and, further, the trade-waters consist almost entirely of brewery-waste waters. As stated under

the heading of No. 15 (Brewery-Waste), such waste water, unmixed with other impurities, is not in itself a bad subject to deal with, but when mixed with domestic sewage it is exceedingly objectionable; it not only ferments, but it evolves sulphuretted hydrogen very rapidly, and for these reasons no time was lost between receiving the sample and proceeding with tests. The sample was taken on the 15th August, 1898, sent to London, and treated immediately on arrival the following day. It appeared to be thin and very dirty-looking, and had a most offensive smell.

To about 6,000 grains of sewage were added 50 grains of salt water, 50 grains of solution of common washing-soda, and 50 grains of solution of iron-alum. The result was rapid precipitation which was hastened by stirring. The effluent and precipitate were separated by filter-paper, and the former was then filtered through silicated carbon, after which it had a very pale yellow colour and a most offensive smell. It was precipitated again with the same ingredients and the addition of a few drops of ammonia; this last proved a beneficial addition, and after slightly stirring, which hastened the precipitation, a dull-looking effluent was obtained. This was filtered through 8 inches of granulated charcoal and 3 inches of coal-dust, followed by silicated carbon; the effluent thus obtained was clear and colourless, but had a slight smell.

General Observations.

Except in the case of the treatment of sewage by electrolysis, the Author is not aware of ordinary salt water that has not had a current of electricity passed through it having ever been used or tried. It will be observed that salt water played an important part in the precipitation of nine of the seventeen varieties of foul water given in the list.

Iron-alum is a very useful and easily-obtained precipitant. Out of the fifteen samples tested (two given in the list of seventeen not being worth testing), in nine cases this proved the precipitant to be used, occasionally by itself, but more often in conjunction with something else, such as salt water. It is inexpensive, as shown at the commencement of the paper, clean and easy to use. The crystals are readily dissolved in water, and it is best to use it in the form of a solution. A good proportion is 160 grains in one gallon of water. Then to each gallon of waste should be added ½ pint of the solution, and this would give 10 grains of iron-alum and ½ pint of water to each gallon of waste, or a volume of precipitant equal to one-sixteenth the volume of

waste, so that a factory discharging say 50,000 gallons of waste a day, would have to provide works capable of dealing with about 53,000 gallons, an addition which might be called insignificant, unless the supply of water was deficient, in which case the purified effluent might be recovered and used for the purpose. The use of the solution entails the provision of a tank to contain it, the flow from which should be controlled automatically. In the use of iron-alum, as in the use of all other precipitants, the proportions must be determined according to the waste to be treated, and the above is only meant as a good average proportion.

It may be taken generally that waste water from chemical works, or any water containing spent or waste acids, and waste from fellmongering and tannery works, should be treated with lime, such treatment to be followed by suitable filtration. In filters, the commonest and most easily obtained mediums are recommended. They should be composed of furnace-cinders broken small, coke, coal-dust and very fine gravel; and in many cases manganese dioxide is an indispensable medium. These mediums should be in layers between 9 inches and 1 foot in depth, or sufficient to give a total filtering-depth of about 3 feet. If a greater depth of filter than 3 feet is required, it is advisable to have two distinct filters and not one filter of 6 feet or 7 feet in depth. The order of placing the filtering mediums should be carefully observed. As a general rule, when the use of manganese dioxide is necessary, this should be at the top, and the fine gravel should be at the bottom, but this is only to be taken as a general idea, and not by any means as a fixed rule; the order of placing must be determined according to the waste to be treated.

It is impossible here to enter into the question of the treatment of sewage, although two samples of sewage were included in the experiments; these were included, as they were samples containing trade-waters. Under the most favourable circumstances, that is to say, if a system of suitable chemical precipitation and artificial filtration is adopted, and if the land is of the best possible character for filtering-purposes, and the sewage to be dealt with consists of the ordinary flow of domestic sewage unmixed with trade-waters, then an area equal to 1 acre for every 2,000 of the population may be considered adequate. Now, supposing the flow of sewage to be at the rate of 30 gallons per head per day, which is no uncommon quantity, it means that this acre of land has to receive and deal with 60,000 gallons a day, equivalent to a rainfall of 2·6 inches per day for every day in the year. If

chemical precipitation without artificial filtration is the method of treatment proposed, then, if the land is thoroughly suitable, 1 acre per 1,000 of the population may be allowed, equivalent to 1·3 inch of rainfall per day, taking the daily flow of sewage at 30 gallons a head as before.

Two questions present themselves with regard to treatment of sewage by irrigation:—The suitability of such treatment, and the area of the land. As to the first question, one of the experiments mentioned in the Paper seemed to prove that land-treatment in that case was distinctly a mistake, for the effluent filtered through clean gravel and sand (a class of ground looked upon as the most suitable) was actually worse after the filtration than it was before; but there is no doubt that in ninety-nine cases out of a hundred, and certainly where ordinary domestic sewage has to be dealt with, land is Nature's purifier, and in such cases the second question presents itself. It is obvious that no land can stand such a perpetual soaking as it would get by nearly 3 inches or even 1 inch of rainfall per day throughout the year. The maximum allowance should not be more than $\frac{1}{4}$ inch of rainfall per day, and this would mean (if the flow of sewage were 30 gallons a head) that, after chemical precipitation and artificial filtration, 1 acre of land should be used for every 200 of the population; and even then it is a question whether a sewage-farm conducted on such principles could possibly be a success, or whether the land could continue its beneficial action with such continuous soaking. If the crude sewage is to be turned on to the land, the area should be very much increased, that is to say, if it is expected to purify the sewage and to make the land pay as a sewage-farm.

Discussion.

Mr. Hawksley. Mr. CHARLES HAWKSLEY, Vice-President, moved a hearty vote of thanks to both the Authors for the trouble they had taken in bringing such important matters before the Institution.

Mr. Meade-King. Mr. MEADE-KING desired to touch briefly on one or two points in connection with the experiments, before the discussion took place. A perusal of his Paper might possibly give rise to the question of the degrees of purity obtained in the various effluents. Within the last few weeks he had received three samples of waste water from a distillery in Scotland. One of those samples he could not do anything with at all; but with regard to the other two, he was indebted to Mr. Scudder, of Manchester, for an analysis. Mr. Scudder said that the organic impurity of one had been considerably lessened, but not sufficiently so; and with regard to the second, he said that the effluent might be classed as properly purified. He mentioned that case because he pursued exactly the same course in dealing with the waste from the distillery as with the waste from other factories. He thought if there was only one success in that case it might be taken that the effluents from the factories were probably purified. The effluents from the distilleries were far worse to deal with than any effluent he had received from a manufactory. Nevertheless he felt some apology was due, because he was afraid scientists would consider he had been poaching on their preserves in attempting to deal with a subject that possibly belonged more properly to the chemist than to the engineer; but he had long felt that something more should be done to assist manufacturers who were called upon to purify the waste water of their factories than had been done hitherto. If these experiments, with all their shortcomings and the want of chemical knowledge in the operator, were the humble means of causing a simple treatment to be devised, he would feel that they had not been made in vain. They were only laboratory experiments; and what might be a very good system on a small scale might nevertheless prove a failure when tried on a large one. But all the processes proposed were so exceedingly simple that if they were all tried, and every one proved a failure, no harm would be done, because the works put down for them would be applicable to any system which any engineer might choose to adopt. Throughout the Paper mention had

been frequently made of the use of filter-paper. That, of course, was inapplicable in works; but he suggested that if such a thing were wanted, cocoanut-matting might be found a very good substitute. He had made no allusion in the Paper to bacterial-filtration for the simple reason that he thought waste water from a factory contained, in nine cases out of ten, no bacteria to start with. There were other reasons why he did not think bacteria-filters would be applicable to waste water from manufactories, but he did not propose to go into them at the present time. There were two samples (Nos. 16 and 17) of crude sewage referred to in the Paper. They were mentioned as being supplied by places discharging the trade-effluents into the sewers. He had not brought the samples with him, because he thought the identity of the places supplying them would probably be established, which, for obvious reasons, was undesirable. But the fact of mentioning those samples of crude sewage caused him to mention the area of land which it was indispensable for an authority to acquire in order to carry out sewage-purification works. Since the Paper was written, other processes for dealing with sewage had been brought into prominence, and the figures had been considerably altered. They might still hold good in a number of cases, but they had been altered in individual cases. It practically amounted to the fact that no hard-and-fast rule could be applied. Mr. Meade-King.

Sir A. BINNIE felt that he was somewhat incompetent to deal with a question which went very much beyond the path of the ordinary engineer, and into that of the chemist. His experience led him to suppose that trade-refuse was really a very difficult matter indeed to treat. In London it was connected with the refuse of certain breweries and oil-refineries, and when the mixed sewage and refuse from those factories reached the outfall it was a very complex substance. It did not readily lend itself to the ordinary treatment of sewage, in the usual sense of the word, as town refuse. He was rather inclined to agree with Mr. Meade-King that possibly the absence of bacteria from those effluents had something to do with the difficulty of treating it. For instance, the ordinary London sewage could be approximately dealt with by the addition of 4 grains of lime and 1 grain of protosulphate of iron, and produced an effluent not altogether bad—sufficiently good, at all events, to vastly improve the Thames, into which it was poured. His former experience in the manufacturing town of Bradford was that 16 grains of lime had to be used per gallon, and then the effluent produced was of questionable quality. He thought Sir A. Binnie.

Sir A. Binnie. that was largely due undoubtedly to the large amount of trade-refuse of a very mixed description that had had to be dealt with there—the refuse from dye-works, wool-washing works, and bleaching-works, which of course poured into the sewers a large amount of chemical matter, quite apart from the ordinary house-refuse. He thought the Institution was very much indebted to both the Authors for a really scientific attempt on the part of engineers to deal with so very complex a subject. It was gratifying to look at the Table which Mr. Tatton gave, showing what really had been done in the purification of sewage in the large towns of the manufacturing districts, more particularly in the Irwell, Mersey and Ribble districts. The Table was most instructive as showing what efforts were really being made by the manufacturers themselves to grapple with an exceedingly difficult subject. The effluents which had been produced by the processes described were undoubtedly a great improvement upon what had hitherto been considered possible, and he thought in course of time even those effluents would be improved, as processes suitable to the peculiar circumstances of each case were discovered.

Mr. Naylor. Mr. W. Naylor first expressed his thanks to the Authors of the Papers for having introduced the subject. As Sir Alexander Binnie had remarked, it really did involve a considerable amount of chemistry; nevertheless, up to the present, chemists had not been able to settle the matter. It was really a chemico-engineering question. Chemists had been able to lay down certain laws, or to detail the results of certain experiments, but they failed to handle in large quantities—thousands of gallons—the liquors with which they had experimented in the laboratories. That, he thought, was quite sufficient justification for Mr. Meade-King recording the experiments he had made. At the same time he confessed that up to the present he had failed to grasp the object of those experiments. Precipitation applied to sewage was quite a different matter from what it was in the case of trade-wastes. In sewage there was a considerable quantity of albumenoids and partially-suspended colloidal matter, whereas in trade-wastes that suspended matter was not colloidal nor was the liquid difficult to clarify. Further, it was not nearly so objectionable as was the suspended matter in the sewage. Precipitants were used in the case of sewage to effect clarification, because clarification was not effected by simple subsidence; but in the case of trade-wastes, at any rate in the cases cited in the Paper, subsidence was effected without the aid of precipitants if only

there were sufficient space. At the present time what was needed Mr. Naylor. was not so much observation of the character of the precipitate, nor even the mere fact of precipitation. He did not complain about the effluent itself, so far as purity was concerned, having been put forward, but he did think it ought to have been ascertained whether the amount of solids contained after the experiment was greater or less than before, because it very often happened that in removing five or six parts of suspended solids by means of precipitants, there was put into the solution an equal quantity or more of solids which were quite as objectionable as the suspended solids under process of removal. That occurred in an experiment he had made, which was reported to the Ribble Joint Committee. In that case a trial of dye-waste was arranged for. He would read the report as printed in 1896: "A trial of the dyeing-department waste was then arranged for the application of 10 grains per gallon, and I made a start at the beginning of an average working day, at 6 A.M. on the 11th ult. Before starting, the arrangement as to 10 grains per gallon was altered, and it was decided to add precipitants—lime and alumina—in whatever quantities were necessary to produce a visible precipitate, and one likely to clarify the raw liquors. This was done for a period of 12 hours, the crude liquor being divided into two portions in the entrance carrier, one portion being conducted to one tank and the remaining portion to another. The quantity treated with precipitants was 53,000 gallons, and that not so treated 63,000 gallons. The precipitants used were aluminoferric, 95 lbs. (equivalent to 12½ grains per gallon), and lime, 73 lbs. dry (equivalent to 9½ grains per gallon). Both tanks were then allowed to stand for 12 hours; but on drawing off the supernatant liquor the following morning at 6 o'clock, that to which precipitant had been added was not visibly different from the other, except that it was a little paler in colour. Both were turbid and contained a considerable amount of suspended matter. The former contained albumenoid ammonia 0·162, and the latter 0·118 part per 100,000. Now, in examining these figures, it will be noticed at once that while the amount of dissolved solids has been stationary, that of suspended solids has been increased. Some of the precipitant itself has, therefore, apparently remained in suspension." He submitted that wherever precipitants were added for the purpose of removing suspended matter, it should be ascertained whether that suspended matter had been removed, and whether it had been removed at the expense of adding to the burden of the liquor that was being treated. He was pleased to note that Mr. Tatton referred to the

Mr. Naylor. biological treatment of trade-wastes. He was rather disposed to think that in the future the biological treatment of trade-wastes might come about. In the case of most of the trades referred to, the organic matter could be treated biologically if souring could be prevented. There was a good deal of starch in bleach-waste, which soured almost spontaneously. The same applied to brewery-waste, and more particularly to the distillery-waste mentioned by Mr. Meade-King. With bleach-waste, it was necessary, first of all, to eliminate the chemicals which contained chlorine, and which acted as a disinfectant or germicide; but if that were eliminated the only remaining objectionable constituents were the acids, which could be neutralized, and the alkalis which Mr. Tatton mentioned were really neutralised in one place by putting carbonic acid into the liquid. He had made experiments which showed that under those conditions bleach-waste could be biologically treated. In the case of distillery- and brewery-waste, it was very difficult to prevent the souring. Precipitants did not prevent souring, so far as his experience went. Lime was added, but, notwithstanding, after some hours he found the waste acid again; more lime was added, and again it was found to be acid after standing. One way to prevent the souring was to pass the brewery-waste or distillery-waste through a tank containing putrid sewage. By that means the acid-producing bacteria did not really get a chance, because of the putrefactive bacteria in the putrid sewage or settling-tank. The settling-tank was not used for the same purpose as in the septic treatment of sewage; in that case it was used for liquefying sludge; but in the present case it was used to decompose the organic matter in solution into products which were not acid, as would be the case if these substances were left to themselves. The quantities of precipitants mentioned by Mr. Meade-King were in one or two cases much higher than could be suggested or recommended in practice. In one case 100 grains to 5,000 grains was mentioned, which was equivalent to 140 grains per gallon, which he thought very few manufacturers could be persuaded or compelled to use. Another point he noted in the Paper was that Mr. Tatton mentioned that bichromate liquors were used as a boiler-composition to prevent scaling. There was a firm in his district who put it to a better use than that. They precipitated the chrome and recovered bichromate of potash. This was much more valuable than soda, which could be used in its place as an anti-fouling composition.

Mr. Blount. Mr. B. Blount said that he proposed to deal with only one section of Mr. Tatton's Paper, treating of the purification of a

Mr. Blount.

particular effluent, viz., that produced in wool-washing. It so happened that a short time ago he had had to deal with an effluent of that description. There was a large and important district which turned out a quantity of the most filthy effluent, derived from the washing of wool. Raw wool, as it came to the comber and the washer, was composed, not only of wool, but of grease and dirt, and the grease was of a characteristic kind. The raw fleeces, as they came into the hands of the wool-washer, were washed in soapy water, and the greasy suds were collected and subsequently turned down the drain, very much to the detriment of the drain, or the river-course into which the drain led. The river-board who had to deal with the water-course objected, and endeavoured to put pressure on the manufacturer. He thought he could show that the pressure exercised on the manufacturer was a beneficial pressure, because the removal of the grease was at present conducted in a way that was by no means sufficiently good. In the first place, it might be contended that the grease which was in wool, being composed of substances insoluble in water, would be best removed by some solvents other than water. That was a reasonable contention; and the process of removing the grease by some solvent other than water had been tried repeatedly, with the smallest success. Apparently it was possible to remove such grease by a solvent like benzene or carbon disulphide, but it could not be removed so economically, or with such small risk, as it could be by a humble solvent like soap and water. Therefore the wool-washer had fallen back on soap and water, and washed his wool very much as a man washed his skin, and for very much the same reason. Wool, like skin, was greasy with similar bodies, bodies which contained cholesterin, a substance which had the peculiar property of emulsifying with water. When acted on by water, and aided by a little soap, it came away, leaving the wool clean, and gave an emulsion of soapy water containing wool-grease. In thus washing his wool the manufacturer obtained a vast quantity of soapy liquid containing grease, and did nothing with it but turn it down the drain. Wool-grease was worth £6 a ton, and the manufacturer knew it, but he thought it would cost him £10 a ton to get it back. But it did not necessarily cost him £10 a ton, and indeed cost very much less than £6. The manufacturer washing the wool did not regard the effluent at all. In that respect he was wrong, because if he were to turn his attention to the recovery of his grease he would find that the value of the grease that he obtained would more than recoup him the expenditure necessary to recover it. When

Mr. Blount Mr. Blount put that idea, which was a simple one, and quite well supported, before the manufacturers who were so kind as to allow him to see their works and to study their processes in the district he spoke of, they treated him quite shortly. In reply to his inquiry whether they might not be spending more than they need, they said that they were not spending a penny more than was necessary; but a little cross-examination elicited that they really did not know what they did spend. Their steam-consumption was excessive, their plant was obsolete, and they had no notion at all of the real cost of the recovery-process, and so they condemned it. The treatment of that particular effluent was only important in regard to the Papers, in that it illustrated the necessity of examining closely the statements which manufacturers might be disposed to make as to the possibility of treating their effluents. If the effluents would yield them some product which would recoup them even in part for their expenditure on plant for recovering that product, the work of the river-board or other authority would be much simplified. It would never be said under those conditions that a trade was harassed, that the manufacturers were being unduly coerced, that labour would be driven away, and that terrible results would follow. If it was found in one case that people were actually turning down the drains something like £50,000 a year, and were unconscious of it, and believed themselves to be victims when any compulsion was put upon them to retrieve a portion of that £50,000, it could be deduced that other trades might be in a similar position; and these, without being dealt with harshly, would equally be able to purify their effluent to a proper point. That he was not speaking without the book was shown by the figures that had been given by the Author, illustrating what had been done. There was a total of 413 works of the most varied kind, some of which turned out effluents by no means so easy or so profitable to treat as that which he was speaking of. Out of that total, no fewer than 254 had already put down efficient recovery-plants, and another 144 had put down works which were at least tolerable, making in all 400—more than 96 per cent. Such a state of things would not be possible were it not that the cost and difficulty of recovery were very much smaller than might be supposed at first sight. Reverting to the treatment of wool-washers' effluent several points of detail might be considered. The ordinary process of wool-washing, which consisted of putting the wool through soapy water, was not sufficiently systematic to insure that the waste waters should carry away with them their full burden of grease, and, on the other hand, that the wool should

emerge completely washed with a minimum of water. The bad Mr. Blount.
effects of this were, first, that the total volume of the waste waters was unduly great, and the difficulty of treating them was enhanced by their dilution, and in the next place, the imperfection of the recovery of the grease from the waters was increased. Such difficulties might be overcome, or, at all events, diminished, by systematic washing. The present method of washing was only semi-systematic. Further, the cleansing should be done with water that was free from lime salts, or as nearly free as could be obtained—that was, with softened water. At one of the most enterprising manufacturer's works which he had inspected there had been installed an excellent system of water-softening, and the wool was washed with the softened water, as indeed economical considerations would dictate. The manufacturers were fully alive to the necessity of reducing the lime salts in the water to the lowest possible minimum. But, at other factories, and factories of great repute, run, as far as their mechanical conduct was concerned, on equally good lines, that discrimination was not so apparent. There they were washing with unsoftened water, thus increasing the consumption of soap. Diminution of the consumption of soap was good in two ways. In the first place, the actual bill for soap was smaller, and, in the next place, the amount of washing water needed to carry away the soap, plus the grease, was similarly diminished, and the problem of recovering the grease from the soapy water that flowed away was proportionately made easier. The only other point he thought should be considered was the always-difficult question of space. Sometimes works were situated in such a position that even a moderate expansion was barely practicable, and ground on which to put the necessary plant could only be obtained at an almost prohibitive cost. Those cases, considering the small area which was required for the effective treatment even of a large quantity of waste liquor, might be regarded as exceptional. But when a difficulty of this sort arose it seemed to him that the rational course was for those works which were fairly within reach of each other, and had experienced difficulty in obtaining land, to form a small association amongst themselves and acquire a sufficient area for the treatment of their waste liquors, which should be collected and treated jointly. That was perfectly feasible, and it was only a matter of arrangement and of keeping accounts in order to share the cost, or, as he contended, the profit. In the treatment of many effluents the use of ferric salts was advantageous. The use of ferrous salts in the shape of ferrous sulphate was familiar in precipitating sewage,

Mr. Blount. but the use of ferric sulphate instead of ferrous sulphate was not so widely known, and the utility of the ferrous salt only became marked when it was converted, as it was in the usual course of oxidation, into a ferric salt, or rather when the ferrous hydroxide to which it gave rise was converted into a ferric hydroxide. Starting with a ferric salt, and obtaining from it ferric hydroxide, there would be produced a precipitant comparable with alumina, and presenting certain advantages distinct from those of alumina, which in many cases would be preferable both to alumina and to ferrous salts. At present he believed this was so little understood that the purchase of ferric sulphate, which was the ideal chemical for treatment of the kind under consideration, was not easy, and at some places it had to be prepared on the premises. He thought enterprising chemical manufacturers should be prepared to put on the market a good ferric sulphate at a cheap rate. There was no reason it should be particularly pure, but it should be sold at a price comparable with the so-called "aluminoferric"—which, by the way, contained no iron. With regard to Mr. Meade-King's Paper, the Author had given an account, which was advisably brief, of experiments he had made on precipitating certain effluents from works of different kinds, and those experiments were no doubt carefully performed and faithfully recorded. But it appeared to him that Mr. Meade-King had somewhat missed the point which was really before the Institution. Clearly the effluent from an industry even of a particular class might vary from time to time, from day to day, and from works to works; whereas the Author appeared to conceive that an effluent from one works, say a paper-mill, was very much like the effluent from another works of the same class. Every effluent must be studied on its merits, and must be studied in one of two ways—either the chemist must examine analytically the composition of that effluent, and must determine its properties and decide on purely chemical data what was its best precipitant, or, if he wished to proceed by the other and empirical method, he must make large-scale experiments. It seemed to him that Mr. Meade-King fell between those two stools. He had made no attempt to discover what was the actual chemical constitution of the effluents he had treated, and he had also failed to carry out the other method of experiment by making his experiments on much too small a scale. Therefore, while not wishing to pass any stricture on Mr. Meade-King's work, which it was well to have recorded, he thought it would have been much more valuable had he pursued one or other of those methods which he had indicated.

Mr. BALDWIN LATHAM considered the subject of the Papers of very great importance to the country, as a vast amount of pollution was taking place in all the streams of great manufacturing towns. From the list of works given by Mr. Tatton, it would be seen that the proportion of success by the processes which were adopted was variable, but no description was given in the Paper of what the particular processes were. For instance, in the case of bleach-works, 60 per cent. appeared to be unsuccessful. The refuse from bleach-works no doubt sometimes passed into streams as chlorine in a free state, which was extremely noxious; in fact he did not know anything more destructive to the fisheries in many of the rivers than free chlorine. He had had to advise in such cases, and he had found a very simple method by which chlorine could be removed or rendered innocuous, and that was by simply treating the effluents with silicate of soda and lime. If silicate of soda was used, the chlorine combined with the soda and formed common salt, while the lime itself combined with the silica and formed an insoluble precipitant, and very copious precipitation took place. Then again, the process by which tan-water was dealt with was not stated in the Paper. In 1881 he had to carry out some purification-works for two large tanneries at Nantwich in Cheshire, and he consulted Mr. Charles Cresswell at the time with regard to the treatment of the waste. The treatment adopted had turned out remarkably successful, a liquid as clear as spring water being turned out from those tanneries. The method of treating the waste was as follows. A tank was constructed at a sufficient depth below the level of the vats in the tan-yards, and into that tank the tan-liquid was allowed to gravitate. When in the vat it was mixed with sulphate of iron in the proportion of 9 lbs. to 100 gallons. After it had been thoroughly mixed and incorporated the liquid was like ink, and probably could be used for the same purpose. The refuse from the lime-pits was then turned into the tank at the rate of 200 gallons from the lime-pits to 100 gallons from the tan-pits, and immediately separation and precipitation took place. The whole of the liquid and solid was then pumped through filter-presses, so as to remove the solid matter, and the liquid was passed on to what were now called bacteria-filters, filters composed of alternating layers of fine sandy soil and burnt ballast. The result was most successful. With reference to the point which had been mentioned in the Paper that the use of lime was injurious to the process of pressing, ordinary sewage-sludge could not be pressed without the addition of lime, and about 5 per cent. of all the sludge pressed consisted Mr. Latham.

Mr. Latham. of free lime. But the case mentioned in the Paper was not pressing in the ordinary sense; it was really hot pressing, such as that by which oil was extracted, and not the ordinary sludge-pressing which took place in most sewage-works. It might otherwise appear that in all great works of sludge-pressing some mistake was being made by constantly adding the quantity of lime which was found necessary. The gummy character of the wash-water from silk-works rendered it most difficult to deal with; as a rule it required two processes to get anything like a purified effluent. He found, even in a particularly difficult case where experiments were carried on in connection with the effluents from Messrs. Lister's works at Bradford, that a good effluent could be produced, such that the water might be used over again in the factory, at a cost not exceeding 6*d.* per 1000 gallons; so that in most cases it would have paid the manufacturers to introduce a perfect system for purifying the effluent. He agreed that in all manufacturer's refuse it was far better to deal with the liquid in its concentrated form, so as to get a good result before general treatment of any slightly impure liquids. With regard to Mr. Meade-King's Paper, he certainly thought that the whole of the experiments were carried out on too small a scale to be of any practical use. He could not understand what Mr. Meade-King meant by the use of salt water; salt water might mean any degree of concentration of salt in the liquid, and he could not understand whether it was water containing common salt or sea-water. It was well known that sea-water was very useful as a precipitant. It contained chloride of magnesia, which was a most excellent precipitant, and by merely admitting sea-water into tanks with sewage and other liquids after treatment with lime, a remarkably good result was obtained. But nothing was said in the Paper as to the quantity of salt in the water which was used. Salt was certainly a disinfectant if used in sufficient quantity. Again, there was another material mentioned by Mr. Meade-King which he had experimented with in sewage-works, namely, tannin. There was no doubt that some of the salts of tannin were of very great value in the treatment of sewage. It was found that where a salt of tannin had been used—he was speaking only of a chemical process—the sewage was afterwards free from sewage-fungus, which could not exist in water treated with tannin. It was a great desideratum to get rid of that bugbear, which was the dread of all sewage-engineers. If sewage-fungus was eventually got rid of, it was generally believed that a great degree of sewage-purification had been effected.

Mr. W. J. Dibdin remarked that in the purification of foul waters the one essential feature was the question of cost. There was no difficulty in purifying any foul water to any desired degree if the necessary cost was incurred. He greatly regretted, therefore, there were not more details given in the second Paper in this respect. The process of purification by means of land was undoubtedly one of a biological character, due to living organisms in the earth. The late Sir Edward Frankland was one of the first men to show that some action taking place in land was the purifying element, and later experiments had demonstrated that this action of land was almost entirely due to bacteria, and that it was the bacteria which were Nature's agents in Nature's own purifier, the land. If that point was clear, it did seem a pity that the Author had not considered the application of the question somewhat further. Bacterial filtration in connection with the purification of trades-waste had been in use for many years, and it seemed a great pity that a feature which had forced itself so definitely upon the attention of all experimentalists at the present time in regard to that question should have been overlooked, because the Author said that with certain preliminary chemical processes they had to resort for the final purification to Nature's purifier. Let that position be accepted, and let it be known definitely how things stood, only, instead of using an indefinite expression, "Nature's purifier," a more definite expression, such as "bacterial action," should be used. He did not think the bacteriologist would say for one moment that in every case the waste from manufactories could be treated directly by bacterial action. It would be a good thing if it could be done, but it could not be done. For instance, taking that very common refuse from works, lime, it was one of the most potent antiseptics that could be had. The caustic action of the lime destroyed every living organism, and no bacterial action would be obtained. That point he had dealt with before the Institution in 1887,[1] and it was now an established fact. Admitting that there were certain cases where the waste from manufactories could not be treated by bacteria or "Nature's purifier," or whatever term was used, without some preliminary treatment, the question was raised as to what that preliminary treatment might be. The use of ferric salts for sewage-purification had been recommended as far back as 1860, and the virtues of ferric salts were very well known amongst those who had had experience of Mr. Dibdin.

[1] Minutes of Proceedings Inst. C.E., vol. lxxxviii. p. 155.

Mr. Dibdin. the question. The only difficulty with regard to ferric salts was their expense. A ferrous salt was very cheap, and ferrous sulphate had been obtained at about 16*s.* a ton delivered in London. Ferric salts were difficult to obtain: they had to be bought in solution, and there was a heavy charge for carriage. It was better, therefore, to trust to the action of a ferrous salt and its power of carrying oxygen from the atmosphere to the organic matter, and get as much work out of the iron in its various phases as possible. There were many cases where ferrous salts did not appear to touch refuse at all, and no precipitation could be obtained, but a little direct ferric treatment would give a very good result. He had frequently found that to be the case, and there was no doubt that in certain cases ferric salts were very useful indeed. But again came in the question of the relative cost, as well as of relative efficiency. There was also another point with regard to the use of ferrous sulphate, although it was a small matter, viz., the mechanical action obtained by the use of ferrous sulphate, which was somewhat of an advantage. He came to the conclusion from a large number of experiments that in certain cases it was so, but it had been considered in relation to particular cases, and therefore had to be dealt with very carefully. With regard to the use of iron-alum, there might be cases of waste-discharges from manufactories in which the use of alum was an advantage, but he ventured to think that as a general rule iron-alum should be applied very carefully indeed, or otherwise considerable expense would be incurred with a very slight advantage. The point raised by the last two speakers as to the treatment of concentrated sewage was one which he had dealt with before the Institution in 1887, and he had shown by definite experiments that, so far as the mechanical treatment of any liquid of that kind was concerned, it was desirable that the liquid should be kept as concentrated as possible. He made very definite experiments upon a series of solutions of different strengths, and the result was that the albuminous matters were carried down in a concentrated solution with very much less expense than in dilute solutions.

Mr. Guttmann. Mr. O. GUTTMANN noticed that Mr. Tatton had given a number of very good specimens of treatment of waste waters from factories on a large scale, and he could find nothing but praise for the way in which they had been carried out. With reference to the wool-manufacturing and dye-works of Messrs. Kelsall and Kemp, he did not find the quantity of water that was treated daily or hourly stated, and therefore the amount of sulphuric acid; being

used per 1,000 gallons of water was not apparent. From the statement of cost he reckoned that about 23 tons of sulphuric monohydrate was being used a year. If that was the case, then there would be a very dilute solution of sulphuric acid with which the sludge was well mixed. He could not understand the Author when he said "the surplus acid drains through the matting-filters into the collecting area below and the sump well O, whence it is pumped by an 'aqua-thruster' into the precipitant tank for use over again." If that acid was so dilute, and had been acting on the sludge, it was not quite clear to him how it was to be used over again, unless considerably larger quantities of acid were used. As to the use of bichromate as a softening medium or boiler-composition, this was patented some years ago, but had not proved to be a success, and he doubted whether it would be capable of competing with the ordinary sodium carbonate for softening water. He did not see the result on the feed-water stated, nor the hardness of the water before and after treatment. With regard to Mr. Meade-King's Paper, he thought the Author could have shown the results in a little Table consisting of fourteen lines, each line corresponding to one of the works from which the waste water had been taken, and the headings, corresponding to the different agents used for testing, marking in each column the test on the water. Instead of that, Mr. Meade-King had given perfectly empirically a number of appearances in water which had been treated by five heterogeneous re-agents. Probably any chemist would have told him that sulphuric acid would have no effect. Instead of preparing carefully a decoction of oakbark, he might more easily have got some tannic acid. Washing-soda was not quite the proper form in which one would take sodium carbonate for making a re-action, and Mr. Dibdin had stated what little effect ferric ammonium sulphate could give. Most of the waste waters in factories, when they had been treated with either a precipitant or a chemical re-agent, might be clear and limpid, without smell, and not offensive to all intents and purposes; but when put into a slow shallow river, or into a pool, or spread over fields, after a few days they might develop fungus. He found no statement from Mr. Meade-King as to the effect in that direction. Mr. Guttmann

Mr. H. A. Roechling remarked that all who had known the rivers of Lancashire before the establishment of the Mersey and Irwell Joint Committee, and who had visited them within the last six months or so, would agree that, through the wise and conciliatory policy of the Board, a great improvement had been effected in the waters of the Lancashire streams, rivers, and Mr. Roechling.

Mr. Roechling. brooks; a result which eminently justified the establishment of this body, and one which led to the hope that it would continue to do its work until the whole of the rivers had been reasonably purified. But work of that kind could not be done unless the policy which directed it was a conciliatory one; and the Mersey and Irwell Joint Committee had been very happy in the way they had got the manufacturers to co-operate with them. They had not been persecuting the manufacturers, but they had been trying to convince them. They had even adopted, if he might use the term, a forgiving policy where such a policy seemed to them to lead to good results. But, on the other hand, they had not hesitated to use a strong hand against offenders who were not amenable to any other treatment. It was that conciliatory policy of the Mersey and Irwell Joint Committee which had brought about such good results. In other places he had observed rather a different policy, a policy by which manufacturers had not been asked to co-operate with the Boards, but had been driven from pillar to post, until, refusing to be buffeted about any longer, they had been driven to combine, and had refused point-blank to do anything more. The result was that the law was a dead letter, and the authorities defeated their own ends. There was one point which was of interest to all those who had to deal practically with this question, and upon which Mr. Tatton might throw a little light in his reply, viz., what had been the relation in Lancashire between the powers of Private Acts of Parliament and General Acts of Parliament. For instance, it had been repeatedly stated that a General Act of Parliament could not repeal a Private Act; that it was necessary, in order to get at certain offenders, to have a Private Act which repealed a former Private Act. As, no doubt, Mr. Tatton had had to deal with three kinds of Acts, Public General Acts, Public Local Acts, and Private Acts, it would be interesting to know in what relation they stood to each other, and whether they had caused him any serious difficulty. He did not know whether it was correct, but it had been stated that manufacturers in this country had been behindhand in regard to the treatment or the utilization of their waste products. When abroad he had been able to see a good many such works, from which it was said manufacturers had realised a considerable profit, but unfortunately he was not able to go into the figures. It stood to reason that if a manufacturer could be convinced that it was to his own advantage to establish works of that nature, he would be very ready to do so. On the other hand, manufacturers might object to doing so, as, with all the

other difficulties they had to contend with, works for the utilization of waste products might not bring in any return. When dealing with the question of utilization of waste liquors from manufactories, he thought a broad dividing line ought to be drawn between districts where there were public sewers into which the waste liquors could be discharged, and those where such sewers did not exist, or where they were not large enough to deal with the liquors. The manufacturers in the latter districts were bound to establish works of their own, if the sanitary authority insisted on it, and the degree of purification to be obtained at those works had to be governed by the character and nature of the stream that took the effluent. But where there were sewers which were capable of taking all the waste liquids of the manufactories in the district, he thought it was the wiser policy of the two, instead of calling upon manufacturers to establish works of treatment of their own, to let them discharge their waste liquids direct into the sewers. In this respect he thought questions of that kind ought to be looked upon from three different points of view —first from the sanitary point of view, then from the social-political point of view, and lastly from the social-economical point of view. Unless the question were looked upon from those three standpoints, wrong conclusions were apt to be drawn, and matters might be viewed far out of their true proportions. He would first direct attention to the expense connected with works of that kind. A serious expense to works in crowded towns and in thickly-populated districts was the area of land required. From the figures given by Mr. Tatton, he thought that Messrs. Clay and Sons had about 1⅓ acre, Messrs. Sydall Brothers about 1½ acre, and Messrs. Kelsall and Kemp about ⅔ acre. When land had to be bought—even if it could be obtained in crowded towns, which was often very difficult—it had to be paid for sometimes at the rate of from £5 to £10 per yard. The question of land in thickly-populated districts was therefore a most important one in the treatment of manufacturers' waste liquids. Then came the question of the cost of the plant, and the figures given by Mr. Tatton ranged from £650 to £6,000. Those were not sums one would naturally be prepared to spend, unless one was absolutely bound to do so. With regard to annual working-expenses, Mr. Tatton gave figures ranging from £150 to £530, and when, bearing these figures in mind, investigation was made from an analytical point of view into the results obtained for all that expense—and in that respect he would refer to the analyses attached to Mr. Tatton's Paper—he thought rather a curious case presented itself. Mr. Roechling.

Mr. Roechling. If these analyses could be taken as fair averages, all the works mentioned managed to deposit their suspended solids. But in reference to the solids in solution the case was widely different. Messrs. Kelsall and Kemp effected a marked improvement in the solids in solution, but in the other works he thought the solids practically remained the same as they were before, and in one they were actually worse than when the crude stuff entered the works. If to this was added that, even with the best of treatment, in crowded towns the works were apt to produce unpleasant smells and be a nuisance to the neighbourhood, and that, further, even with the best intentions the observations carried out at those works by the authorities were apt sometimes to be very irritating, the question forced itself upon one's mind whether it would not be better to avoid all those difficulties, and allow the manufacturers, where possible, to discharge their waste liquids direct into the sewers in the crude state. He knew perfectly well there were cases where that could not be done, where the discharge of manufacturers' crude liquors into the sewers caused difficulties which made the exclusion of the stuff in that state a matter of necessity. Where that was not the case however, and where no unreasonable difficulties presented themselves to such a treatment, then he thought, in the interests of all concerned, the manufacturers should be allowed to discharge their crude stuff into the sewers. If he might be permitted, he would like to illustrate that by a case in point. Some time ago a small town in a manufacturing neighbourhood adopted a proprietary process of sewage-treatment long after the various manufacturing works had been established. In fact, had it not been for the manufactories of the district there would have been no rates to pay or collect, as with the removal of the manufactories from the district the ratepayers would probably have removed also. But the authorities employed that proprietary system, and after a while the county authorities called them up for polluting one of the streams in the county. Thereupon the patentee of the process fell back upon his remedy and said, "You must call upon the manufacturers to treat their crude wastes before discharging them into the sewers, otherwise I shall not be able to treat the sewage at the outfall." In consequence of that the authorities went in for a system of espionage to try and find out what the manufacturers discharged. They attached bags and other things to the outlets of the drains from the manufactories into the sewers, and employed all sorts of irritating and annoying proceedings, so that in the end the manufacturers combined and said, "We shall not do anything further; we will do what is reasonable,

but we do not see why you should harass us for the benefit of a patentee who is not a ratepayer of the district, but takes the money out of the district; why should you compel us, who are the mainstay of the district, to spend money for the benefit of an outsider?" In the event the authorities fell back upon the only proper course; they abandoned their system of treatment and established a new process, which it was hoped would avoid all the difficulties. The manufacturers, after all, were the life-blood of this country, and if their energies were sapped by harassing restrictions, added to the difficulties not infrequently experienced with the labour employed in their works, they would not be able to compete with others, and they would then have to shut up their works and remove to another part altogether. Mr. Roechling.

Mr. G. M. LAWFORD assumed from Mr. Tatton's Paper that the works referred to and illustrated in the Plates were in unsewered districts. He agreed with Mr. Roechling with reference to the hard and fast line to be drawn between the sewered and unsewered towns. His personal experience of the disposal of sewage from manufacturing districts was that, in the generality of instances—*i.e.*, except in those towns where acidified trade-wastes were largely in excess of the flow of domestic sewage—no treatment was necessary previous to the discharge of the liquid at the outfall; and that in by far the greater number of cases, the liquid wastes from manufactories, when combined with ordinary domestic sewage, could be treated satisfactorily by intermittent filtration. This could be effected either by artificial bacteria-beds, or through land, or by a combination of both, where the quality of the land was not suitable for natural intermittent downward filtration. He would like to mention four instances of successful land-treatment of sewage combined with trade-liquids, two of which were carried out by Mr. Bailey Denton, and the two latter by his son Mr. Eardley Bailey Denton in conjunction with himself. In the case of Dewsbury, with a population of 30,000, and a daily sewage-flow exceeding 1,000,000 gallons, the entire volume was purified without any artificial treatment on about 70 acres of very sandy porous soil, which was of course eminently suitable to the purpose. In connection with the Paper, the manager of the sewage-farm was written to, and he wrote back to say that, although the sewage consisted chiefly of dye-wash, the effluent which went into the River Calder was very good, so good indeed that the neighbouring mill-hands came to bathe at the outlet, the discharge from which formed the only clear water for miles around. At Barnsley, with a population of 35,000, and Mr. Lawford.

Mr. Lawford. a daily sewage-flow of 1,500,000 gallons, the entire volume was treated satisfactorily in the same manner on an area of 80 acres; although in that case the soil was not so free as at Dewsbury, yet the sewage was of the same character, and he might add, from his own personal experience, that it was equally foul. At Leek, one of the centres of the silk-industry, practically the whole of the trade-wastes were discharged into the town sewers, and were disposed of on 16 acres of land. That land was partly clay and partly of a free nature, and all the sewage which was put over the land was treated first in very small artificial filters. At Crewkerne, with a population of 4,000, the sewage consisted chiefly of dye-wash from Dent's and other glove-factories, and a daily volume of 150,000 gallons was treated on 13 acres of partly heavy and partly light land, with only very small artificial filters as a preliminary treatment. He had watched the sewage-flow at Crewkerne during the period of maximum flow, and had seen it change from the ordinary grey colour of sewage to black, from black to bright red, and from red to brown, all within 6 hours. He had had the effluent from that farm under observation for several months, and although it only discharged into a very small brook, which was a tributary of the Parrett, there was absolutely no sign of secondary putrefaction or sewage-fungus, and the farm had been at work for nearly 4 years. Mr. Meade-King's experiments, although, as Mr. Blount said, on a laboratory scale were extremely interesting, but he would like to supplement Mr. Meade-King's experiment No. 8 with the observation that a filter on the same lines, where the filtering medium was suspended in trays with a space between each tray, had been designed a short time ago by Mr. Scott-Moncrieff, and had been in operation at Caterham Barracks, where the sewage from the barracks, with a population of about 1,500, was exceptionally strong; and he believed that the improved results of the filtration of the effluent through those oxidizing trays was largely due to the increased aeration. He thought the thanks of the Institution were due to the two Authors for their Papers, which were not only extremely interesting to the members of the profession, but also to the public in connection with the health of dwellers in riparian towns.

Dr. Rideal. Dr. Rideal thought it should be realised that the old Rivers Pollution Prevention Act of 1876, if properly worked, would give manufactory-effluents free from sludge, and he could not quite understand the difficulty in the Mersey district which prevented that Act from being put into force. Their present Act seemed to be much more irksome to the manufacturers than the old 1876

Act. That was shown by the fact that the manufacturers had spent large sums of money in dealing with their waste liquor. At Bradford, where a special Act was passed to deal with the manufacturers' refuse, the Corporation had not availed themselves of their powers, and the Act was still in abeyance; so it would seem that these special Acts giving power to authorities to compel manufacturers to deal with their waste liquors had not been the success that had been hoped. With regard to the materials employed by Mr. Tatton for precipitation, Mr. Blount had dealt pretty fully with the question of the aluminoferric, and Mr. Dibdin had pointed out that ferric chloride was used in 1860 by the late Professor Hofmann as a precipitant for sewage; but it had yet to be seen what were the relative merits of ferric sulphate, aluminoferric and ferrous sulphate, and ferric chloride. He rather thought himself that the iron salts and alumina would behave very similarly when the iron was in a ferric condition; he thought when the ferrous salt was used the same effect was not obtained as from a ferric salt. But ferric sulphate and ferric chloride would probably give similar clarification. As there was a difficulty in obtaining the ferric salts on a large scale, the way in which it might be overcome seemed to him to be by using a mixture of ordinary aluminoferric and a small quantity of ferrous sulphate. That, he believed, would give very satisfactory results in practice. He was interested in Mr. Baldwin Latham's experiments dealing with trade-refuse. In his experience the really difficult substances which had to be dealt with were the solids in suspension, and floating oils and grease. Gas-liquors were specially objectionable in that way, and amongst the materials which had to be carefully considered were the liquors from bleach-works which contained small quantities of free chlorine. He believed the addition of ammonia liquor to free chlorine would have very beneficial results. Chlorine passing through precipitating-tanks when different precipitants had been used had appeared in the effluent. That was notably the case at Swinton. In the inquiry of the Manchester Corporation 10 years ago, Swinton was carefully examined by them, and it was found after ferric-sulphate precipitation that the smell of chlorine persisted. Dr. Rideal.

Mr. R. A. Tatton, in reply, begged leave to express his thanks for the kind way in which his Paper had been received. With regard to Mr. Blount's remarks respecting the difficulties experienced at Bradford in consequence of the discharge of trade-waste from wool-scouring works into the sewers, the same difficulty was experienced at Rochdale, the centre of the woollen-industry Mr. Tatton.

Mr. Tatton. in Lancashire. This particular trade-waste was found to complicate the treatment of any sewage or other waste with which it was mixed, whereas, when taken by itself, it was by no means difficult to deal with; but—and this was the secret of success—the more concentrated portions of the waste, namely, those containing the grease and soap, must receive a preliminary treatment by themselves. The effluent from this treatment might be discharged into the drain containing the rest of the waste from the works and be treated with it. He thought the difficulty which was experienced at the sewage-works might be, to a considerable extent, overcome in a similar way by insisting on some preliminary treatment of the more concentrated liquors in the mill, before the waste was discharged into the sewers. The tanks required need not be large, as the volume of this concentrated liquor was not great. In fact, if no space for the construction of tanks could be found outside the works, it would probably be possible to make them of sufficient capacity under the floor. He was much obliged to Mr. Baldwin Latham for calling attention to the neutralization of the lime by means of acid at Messrs. Kelsall & Kemp's works. The pressing referred to was, as Mr. Latham said, hot pressing, the presses being heated by steam. The quantity of water dealt with at Messrs. Kelsall & Kemp's was 180,000 gallons a day, of which 100,000 gallons were dye-water, and 80,000 gallons piece-scouring water. The object in pumping the acid which drained from the sludge back to the precipitant-tank was not so much to secure economy as to prevent the acid finding its way into the stream and causing trouble to manufacturers lower down (see analysis, p. 18, sample 5). With regard to the admission of manufacturers' trade-waste into the sewers, one serious difficulty was the abstraction of water from the river between the point where the manufacturer took it into his works and the point where it was again delivered into the stream, at the outfall-works of the local authority. This, in some cases, was a considerable distance, and any riparian owner on that portion of the stream would have cause for complaint. He could not agree with Mr. Lawford that no previous treatment was necessary before discharging manufacturing-waste into the sewers, but this preliminary treatment should not be more than was necessary to attain the objects in view; the object aimed at should be to intercept any solids in suspension which might cause silting up of the sewer, and, in the case of certain trades, such as wool-scouring, to adopt such treatment as would prevent undue difficulties at the outfall-works. In reply to Dr. Rideal's question, in

what particulars the new Pollution Act of 1892 was superior to the Act of 1876, the chief point in which it was superior was as regards solid matter. Under the old Act a manufacturer could tip his cinders and rubbish on the edge of the stream, to be carried away by the first flood; and, so long as he did not tip it actually into the stream, he was exempt. Under the new Act he could be prevented from putting it so that it was liable to fall or be carried into the stream. He was also prevented from discharging the solid matter or sludge which accumulated in reservoirs. Formerly an enormous quantity of cinders was got rid of in the way described, and as long as this form of pollution was allowed, it was almost impossible to get manufacturers to take any steps in the direction of purification. It was generally recognised that solids must be dealt with first, and there could be no doubt that the new Act had been of great assistance in this direction. No difficulties had been experienced with special and local Acts, as by the passing of the 1876 Act, any prescriptive right to pollute ceased to exist. He was glad to note that Mr. Roechling testified to the improvement which had taken place in the rivers, and on this point he would like to say a few words, as statements to the contrary were made from time to time. A statement had been made in the House of Commons last year by one of the Lancashire members, when Sir Francis Powell's Rivers Pollution Prevention Bill was before the House, that not five shillings' worth of good had been done. That statement was a very serious one, when it was considered that £300,000 has been spent by manufacturers on capital cost alone, and that the cost to local authorities had run well into millions. That the statement was incorrect, however, was obvious to anyone who had carefully watched the conditions of the rivers during the last few years, and he would give a few instances to show that the manufacturers themselves were deriving benefit from the improvement. One of the works described, namely, that of Messrs. R. Clay, was situated on a tributary of the River Mersey, and during the past summer the whole of the water of the stream had been utilized in the works for manufacturing purposes. About a mile below, there was a bleach-works, and the supply for this works was also derived from the stream. Before Mr. Clay had brought his works up to their present standard, when, in fact, only tanks Nos. 1, 2, 3 and 4 had been built, constant complaints had been received from the bleacher below that his water-supply was being fouled, but during last summer, which was exceptionally dry, not a single complaint was received. Another instance was that of a bleach-works in Bolton,

Mr. Tatton.

Mr. Tatton. where a considerable portion of the water-supply was now derived from the River Croal, in spite of the fact that there were four dye-works, two paper-works, and several bleach-works discharging their effluents into the stream above. The use of this water for bleaching purposes would have been quite out of the question a few years ago. Again, on the River Medlock, which was a tributary of the Irwell, the improvement in the condition of the river meant a saving of £500 a year to a large dyer in Manchester, as he was able now to use river-water to a great extent, instead of buying town water. These instances might have been supplemented by many others, but he thought they would be sufficient to prove that the money which had been spent had not been wasted, and that it was worth while to continue the efforts to purify our rivers. The work must necessarily proceed slowly, otherwise strong opposition would be raised which might be fatal.

Mr. Meade-King. Mr. MEADE-KING, in reply to the Discussion, wished to explain shortly, in reference to the remarks of Mr. Naylor, that the main object of the experiments was to devise a simple and efficient method of dealing with waste waters, and at the same time to tabulate for ready reference the various trades involved and experiments tried, for the sake of those called upon to deal with waste water from works engaged in a particular trade. An unlooked-for object was also attained, namely, the design of a filter capable of dealing with a quantity of water, per square yard of filter, far in excess of any filter hitherto used—a matter of importance to manufacturers having only a limited space for purification-works. So far, this filter was only in an experimental stage, but the working model, made for the sake of the experiments, had given most satisfactory results. With regard to the biological treatment of trade-waste waters, he had explained in his opening remarks why he had made no allusion to bacterial filters for the treatment of the waters, and, apparently, Sir A. Binnie agreed as to their probable inefficacy; but there were other reasons for not using them. It might suffice to state two of these reasons, namely, the space required by works of that description, which in many cases could not be found, much less be devoted by the manufacturer to this purpose; and, secondly, the fact that one of the chief advantages claimed for bacterial treatment was the absence of sludge needing to be dealt with. As pointed out, not only in the Paper, in which the information given on this point had been obtained from direct evidence, but also in Mr. Blount's remarks, it was evident that in some cases, if not in all, the sludge obtained from factory-waste

water was valuable, and instead of being run to waste, should be recovered; therefore chemical precipitation suggested itself as the readiest method of securing the object in view. In fact, Mr. Blount's remarks seemed to point conclusively to the need for precipitation and recovery of bye-products. In speaking of the case in which the quantity of precipitant used was said to be 140 grains to the gallon, Mr. Naylor presumably referred to the experiments tried with the waste water from bleach-works, in which 100 grains of solution of iron-alum were added to 5,000 grains of the waste water. The strength of this solution was fully explained in the Paper, and the Author suggested the use of 20 grains to the gallon, giving the approximate cost such a quantity would entail. Mr. Blount had referred to difficulties experienced by manufacturers in acquiring space on which to put down purification-works, or rather, the necessary plant for the recovery of certain products; at the same time he advised co-operation and the sharing of the profits that might be made if such plant were put down; all of which proved the necessity for a simple and rapid method of treatment—rapid because the space was in most cases limited. Of course effluents from some works would be very likely to vary in character from time to time during the day; that was fully recognised, and was specially mentioned in the experiments recorded in connection with No. 3 (bleach-works). In such cases the chemist, not the engineer, would have to be consulted as to what precipitant should be used; and the process would undoubtedly vary according to the character of the waste water at the time being. As to making large-scale experiments on such a number and variety of waste waters, an undertaking of that character would be beyond the limits of private enterprise. Mr. Baldwin Latham asked what was meant by salt water. This water was obtained by dissolving crystals of sea-water until water was obtained of as nearly as possible the composition of sea-water, and salt water throughout the Paper was intended to refer to sea-water. It was a matter of great interest that a gentleman of Mr. Baldwin Latham's great experience in these matters should concur in the use of sea-water as a precipitant and disinfectant, but it was open to doubt whether its efficacy as such was generally known. The result of a very large number of inquiries made, as to whether it had ever been tried, or whether its effect was known, was that in no instance was an answer received in the affirmative; and it seemed that such a simple expedient might be more often tried with beneficial results. Exception was taken by Mr. Dibdin to the words "Nature's purifier" as applied to the land-treatment of

Mr. Meade-King.

Mr. Meade-King. impure waters, but the Author believed that every step taken in the advance of scientific treatment of sewage was only one step nearer to what would actually take place in a state of nature; the probabilities were, the bacterial filter-bed was merely a concentrated form of land, or, in other words, land made perfect, the same action taking place in both, the same agents being at work. Mr. Guttmann had stated that though waste water from a factory might be made clear and free from smell, it might still develop fungus after a short time in a river or pool, or on fields. Such a state of things was almost sure to occur if clean spring water was bottled and kept for any length of time, but he (Mr. Meade-King) was not aware of any growth of fungus having taken place, after treatment, in the samples of waste waters accompanying his Paper, although they had been kept about eighteen months.

Correspondence.

Mr. Chadwick. Mr. OSBERT CHADWICK had designed, for a firm near Bolton, works for the purification of the waste liquids from the processes of bleaching and dyeing yarns. The bleaching was conducted in the ordinary manner and the usual colours were dyed. The first difficulty which presented itself was to obtain a fair average sample of the effluent. The various departments discharged their wastes direct into the stream by different pipes which spouted forth all-coloured streams, and it was most difficult to ascertain the proportions of the various waste liquors, which changed from hour to hour. Having obtained some approximation to a representative sample, however, experiments were made to discover the best method of treatment. An experimental filter-bed, six feet square, was made and experimented on; and on the results of these experiments, which tended to show that the combined waste could be economically purified by filtration through sand, filter-beds were constructed on the lines of ordinary waterworks filters. The experiments, however, though conducted upon somewhat more than a mere laboratory scale, turned out to be entirely misleading. Filtration on the large scale proved impracticable, owing to the rapidity with which the beds became clogged, and the difficulty of removing the precipitate: consequently filtration was abandoned, and the beds were converted into depositing-reservoirs. Numerous precipitants were tried, but ordinary lime was found to be as efficient as any other. An effluent was pro-

duced which satisfied the requirements of the case, but the arrangement was not altogether satisfactory, the main defect being the absence of an efficient means of drawing off the deposited sludge. Fortunately the site of the original installation was required for a mill; and he was called upon to reconstruct the works in accordance with the experience obtained from the original plant. It was then decided to trust entirely to precipitation, and to adhere to lime as the precipitant. Mr. Chadwick.

The works, in their final form, consisted of an intercepting sewer, collecting the waste liquors from the dye-houses and the bleach-works, and conveying it to a sump, under one of the lowest rooms of the works. There was no land in the possession of the firm below this point, upon which tanks could be constructed to which the waste could flow by gravitation. It was therefore pumped by a steam-pump to the precipitating-tanks situated on a meadow above the works. The tanks were four in number, circular, and 40 feet in diameter, with plumb walls of 9-inch brickwork. The working-depth, that was to say, the upper cylindrical part of the tanks, was between 4 feet and 5 feet deep, so that the charge of each reservoir was between forty and forty-five thousand gallons, or about half a day's supply. The volume of liquor varied much, according to the relative activity in the various departments. The reservoirs were worked in succession, one filling, two standing, and one emptying. The liquor entered near to the bottom of the cylindrical part of the reservoir. The clear water was drawn off from about a foot below the surface, by means of swimming pipes, the outlets of which were near to the bottom of the cylindrical part. To facilitate the collection and removal of the precipitate, the bottoms of the reservoirs were made in the form of inverted cones about 6 feet deep to the apices, at which sumps were formed. The lime was introduced, in the form of lime-cream, about half-way down the intercepting sewer. The lime-cream was produced by means of a machine, the invention of the late General Scott, R.E. The slaked lime was agitated with water, and finally triturated between revolving cast-iron disks. The quantity of lime to be added was adjusted by regulating the stream of water flowing into the machine. For the removal of the precipitate, two sludge-lifters were provided. These consisted of wrought-iron cylinders, 6 feet high and 4 feet 6 inches diameter, each serving two reservoirs. The suction-pipes from these dipped down to the sumps, at the bottom of the cones. These sludge-lifters were worked on the principle of the "monte-jus" of sugar-works, or of the pulsometer pump, except that the valves

Mr. Chadwick. were worked by hand. Steam was supplied from an adjacent range of boilers. In admitting it, a vacuum was formed; and on opening the suction sluice-valve, the sludge filled the cylinder. Closing the suction, steam was readmitted, and forced the sludge up to a trough, through which it flowed to the sludge-pits. So far the arrangement was wholly satisfactory. The sludge was removed as it accumulated in the depositing tanks, without manual labour. The effluent was clear, transparent, and of a pale yellow colour. It might be kept for any length of time without putrefaction or the production of any further precipitate.

The method of disposing of the sludge must be admitted to be crude. It was poured into open tanks, when it slowly dried, until at length it became sufficiently firm to be shovelled out. It was then carted out and spread on meadow land, of which the firm had abundance, being sometimes mixed with ashpit and privy-refuse. It did not appear to have any injurious effect on the grass, even when applied in considerable quantity, nor did it appear to have any manurial value. Experiments were made to ascertain the possibility of concentrating the sludge by means of filter-presses, such as were used for sewage-sludge, but the results were negative. The cloth choked up almost immediately under ordinary pressure, and, if the pressure was increased, the sludge passed through the filtering medium as though it were a fluid. Probably the best way of disposing of this sludge would be to evaporate it to dryness, in shallow iron pans. For this purpose an abundance of hot air could be obtained from the chimney-flue of the adjacent spinning-mill. The sludge, even after drying for some time, contained upwards of 90 per cent. of water, as determined by evaporation at about 150° F. The dry residue was further reduced in weight by incineration at a low red heat, and the residue after incineration seemed to consist mainly of the added lime, tinged with some of the mineral substances used in the various processes. Altogether, the total quantity of solid matter in the dried sludge was so small that it could easily be disposed of by throwing it into the furnaces of the boilers.

He regretted that he could not give statistics as to the quantity of waste liquors treated, or of sludge produced, or an analysis of the effluent. The inspecting officers of the river-authority had expressed their satisfaction with the quality of the effluent, and the firm were content with the somewhat primitive method of disposing of the sludge. The desired end had been attained, and no exact records had been kept. There was, however,

evidence to show that the precipitated sludge re-dissolved or decomposed in the depositing-tanks. This could hardly be due, in the present case, to bacterial action, as it was scarcely conceivable that any living thing could exist in a liquid containing so many poisonous substances. Still, it was difficult to believe that the removal of so small a quantity of sludge would, as was actually the case, suffice to keep down the level of the depositing reservoirs, if some decomposition or re-solution did not take place. He did not contend that the effluent was potable, or suitable for admission into a stream used as a source of water-supply. He considered it, however, to be quite good enough to admit to a river draining a large industrial district. It was out of the question to demand, in the case of a Lancashire stream, a standard of purity that might reasonably be expected in the case of the Thames or its tributaries. A general standard of purity, applicable to the whole kingdom, was impracticable. Each river-authority must fix its own standard, taking into account the interests involved; and to this end it was most desirable that the jurisdiction of the authority should be conterminous with the watershed of the river. Mr. Chadwick

Major LAMOROCK FLOWER remarked that, while brewery-waste was referred to, no notice had been taken of waste from maltings, known as "malting-water." This was water in which barley had been steeped, a fluid which, rapidly decomposing, was a cause of considerable pollution, more especially where it was passed into streams of low volume and velocity. A case recently under his notice proved this fact. A town of large population, the staple industry of which was malting, had some years since properly connected the drains from the malt-houses with the sewers, and the sewage was led to a low-lying piece of land and disposed of. Fears existing that this land would become super-saturated, the authorities took upon themselves, unauthorized, to divert the malting-water into the surface-water drains which flowed into a dead pool of a well-known navigation. During last summer there was an abnormal scarcity of water in the river, and the pool, which was already polluted by the effluent from the sewage of a large town higher up the stream, began to exhibit conditions of increased pollution, and to smell very badly. Fish died in large numbers, and much complaint was made. A strict investigation of the facts showed the origin of the increased pollution, which had escaped notice while there was a good flow of water in the river. Major Flower.

Mr. Hunter. Mr. W. HENRY HUNTER observed that the question as to the possibility of restoring the waters of the rivers in the manufacturing districts to an approximately pure condition urgently called for immediate settlement.

Referring first to Mr. Tatton's Paper, and to the work accomplished by the Mersey and Irwell Joint Committee, it was notorious that for many years the ancient Mersey and Irwell Navigation has been allowed to remain in a derelict condition—a reproach to the district through which it passed and a loss to the nation at large. In 1885 the Act for the construction of the Manchester Ship Canal (which took the place of the ancient navigation) received the Royal Assent. By the Act of 1888 the Mersey and Irwell Joint Committee (and other river-boards) was constituted, and in 1892 the Act which conferred further powers upon that committee became law. Had the ship-canal works never been constructed, Mr. Hunter had little doubt that the rivers and streams in the watershed of the Mersey would have been left in their foul condition; and in his opinion the formation of the Mersey and Irwell Committee was the outcome of the ship-canal project, rather than "of a general feeling in Lancashire and Cheshire that the polluted condition of the river was a disgrace and a nuisance." Since its establishment the Mersey and Irwell Committee had undoubtedly been faced by many difficulties. On the one hand, the object of their existence was the purification of the rivers; the removal from the waters of chemical impurities and of such solids in suspension as manufacturers' refuse and sewage-sludge, as distinguished from the detritus which formed the natural burden of every river. On the other hand, excessive harassing of manufacturing industries and the imposition of undue charges upon the ratepayers of the urban and rural districts were to be avoided. Making all due allowance for this, Mr. Hunter could not admit that up to the present time any phenomenal success had attended the operations of the committee.

The following figures, which were the actual quantities dredged from the Manchester Ship Canal at (1) the Manchester Docks,

—	Manchester Docks.	Partington.
	Cubic Yards.	Cubic Yards.
1895	402,713	55,764
1896	419,390	196,915
1897	382,211	231,383
1898	361,488	202,856
1899	372,105	266,772

where the waters of the Irwell passed into the canal, and (2) the Mersey Weir and Partington, where the waters of the Mersey were received, showed that the solid matters carried in suspension by the rivers were certainly not decreasing to any material extent. The material dredged consisted largely of manufacturers' refuse and sewage sludge. Recent experience afforded proof that the material dredged was largely composed of those foreign substances and was not detritus. Mr. Hunter.

In the watershed of the Mersey a protracted drought was experienced in June, July, and August, 1899, during which time the streams and watercourses (until they suffered pollution) were limpid. The point of repose had been reached in the beds of all streams, both large and small, and practically no detritus was being carried down by them. Mr. Hunter urged the cogent fact that during those months there was no sensible diminution in the quantities of material deposited at the points referred to. As one more than ordinarily interested in the matter, he only hoped that, in the interests of all parties concerned, more satisfactory results of the efforts of the committee and their officers would become apparent, and that Mr. Tatton's statement that, "during the last few years a large amount of work has been carried out for preventing pollution of the rivers of Lancashire and Cheshire," would find abundant justification in the improved condition of the waters of the ship canal, and in a substantial reduction of the quantities of dredging now required to maintain the navigable depth of the canal.

Turning to Mr. Meade-King's Paper, he trusted that the Author would continue his experiments, and would, if practicable, conduct them upon a larger scale. A point upon which observation might advantageously be made, and upon which Mr. Meade-King had laid special stress was the quickening effect of comparatively small quantities of salt water on the precipitants used. If that point were established it would have an important bearing on another branch of river-pollution which could not be shirked much longer in this country, *i.e.*, (1) upon the discharge of sewage and other refuse into estuarial creeks and inlets on the coast, and (2) upon the extension of the provisions of the Rivers Pollution Prevention Act, etc., to such discharge, which at present took place unchallenged and unchecked, with the result that vast injury was accruing in many estuaries. Taking the estuary of the Mersey as an example, into the length of that estuary, which extends from the Rock Light on the Cheshire coast line to Woolston weir (the highest point reached by salt water), in addition to manufacturers'

Mr. Hunter. refuse, crude sewage from a population of something like 1,200,000 persons was being discharged daily. Mr. Hunter understood Manchester experience to have shown that the quantity of sewage discharged daily from large manufacturing towns might be taken at about 40 gallons per head of population, and that from 1,000,000 gallons of sewage 23 tons of sewage-sludge were derived. Applying these figures to the above population it would be seen that over 400,000 tons of sewage-sludge, untreated in any way, were being annually discharged into the Mersey estuary, and discharged too, without any regard to tidal condition. Mr. Meade-King's experiments had gone to show that in salt water that mass of sewage was promptly precipitated and therefore remained *in situ*. Consequently the evil was cumulative. But that was not the only injurious effect, as, owing to the gelatinous character of the sewage-sludge, it formed a matrix through which the silt, carried in suspension by the waters of the estuary, was fixed in position. Hence accretion was undoubtedly taking place—accretion which would eventually have destructive effects upon the lower portions of the tideway. The Mersey estuary was but one case out of many. The question was one which affected nearly the whole of the estuaries of Great Britain, and Mr. Hunter would be glad to know if any pronouncement could be obtained from the members of the Institution upon a subject of such national importance.

Colonel Jones. Colonel A. S. Jones, in common with others interested in sewage-disposal, had often advocated clarification of waste waters at the factories producing them, and congratulated Mr. Tatton on the measure of success attained in his watershed as recorded in his Paper. Experience, however, had shown that a reasonable proportion of such waste water did not prejudicially affect, but, on the contrary, in the case of some factories, such as fellmongeries and leather-works, was advantageous to the purification of town sewage upon a sewage-farm; and when the factory could discharge into a town sewer, the elimination of the grosser solids by simple deposition in tanks at the factories would be sufficient in many cases. In others the chemist would have more certain data upon which to prescribe his precipitating agent for waste water at the factory than could ever be available with the complex mixture of town sewage, upon which so many efforts had been made by chemists without certain purification resulting.

With regard to the general observations at the close of Mr. Meade-King's Paper, he observed that the Author had come to the right conclusion—"land is Nature's purifier"—though Colonel Jones took exception to his parenthesis a little higher on the same

page, because a covering of good loam over the "clean gravel and sand" is essential to its definition of the "class of ground looked upon as the most suitable." The failure of the land-experiment referred to, however, was certainly due, not to "Nature's purifier," but to bad management in not allowing intermittent periods of aeration to the sand and gravel employed, and such failures were common enough; because land was out of fashion at present, and consequently did not receive the attention which was bestowed upon "septic tanks" and "contact-beds" in small areas under the eyes of interested inventors. Colonel Jones.

Mr. Paterson. Mr. MALCOLM PATERSON observed that, in the preparation of Papers on the treatment of trade-effluents, it was important that the nature of such effluents should be clearly defined. He himself had specially inspected the works described by Mr. Tatton at Woodhouse Mill, Norden, belonging to Messrs. Kelsall and Kemp, in connection with a chancery suit, in which, amongst other things, river-pollution was alleged; and he agreed with the Author that they presented a complete and successful arrangement for treating the special class of woollen-trade effluents there produced. He would say, further, that as yet he knew of none so complete in the West Riding, in which the vast bulk of the English woollen-trade was located. But he wished to remark that one very difficult element, the animal oil from wool-scouring, was not present here, woollen yarn and pieces only being washed. The grease-effluent was a mixture of soft water with the oil used in softening the fibre and the soap used for partially washing out such oil. He would like to know the Author's opinion as to whether such a process would answer for the effluent from the washing of raw wool, in which the inherent animal oil presented a difficulty. He would further ask the Author's views as to the wisdom or otherwise of receiving effluents from wool-scouring and dyeing into sewers; of course under proper restriction as to the interception, not only of solids, but of the bulk of the grease. The difficulty he himself had found, in his experience of a good many of such cases, was to secure the honest and efficient working of such intercepting works by the manufacturers. Having known the Naden brook, into which Messrs. Kelsall and Kemp's effluent discharged, 20 years ago, he could testify that what was then a black and fetid sewer was now a comparatively clear stream. This proved the value of the great work carried out under the Mersey and Irwell Joint Board; a work which, unlike that of some less fortunate boards, had behind it to a great extent the moral force of the polluters themselves—a matter of vital

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Mr. Paterson. importance in the restoration of rivers to something more like their natural state, and one reflecting great credit upon the enlightened manufacturers of Lancashire, who, in the long run, would probably find clear streams more profitable than open sewers. He agreed with the Author as to the reception of tannery-waste liquors into the sewers subject to preliminary settlement of the solids.

Mr. Meade-King's Paper was suggestive and original, and many questions arose from it. Was the salt water used in the experiments sea-water, and, if not, what were its constituent parts? What mechanical means of stirring the liquid after flowing into the tank would he employ? Tank-settlement of suspended matter implied comparative quiescence in the liquid carrying it, not agitation. Also, why agitation in the tank? The Author's results with regard to woollen-trades effluents seemed to have satisfied him that filtration of such liquids was of but secondary importance. This in one sense agreed with Professor Dewar's evidence with respect to Bradford sewage, given at a Local Government inquiry in 1894, when he said that the process of dealing with the sewage of that town must be a chemical process, and that no filtration did anything but alter the appearance of the water. It was true that Bradford sewage was not pure woollen-trades effluent, but it was claimed that the very large proportion of such effluent contained in it caused the difficulty. Finally, it was no doubt obvious to the Author that experiments on so small a scale, though suggestive, were not proof.

Mr. Tatton. Mr. TATTON, in reply to the Correspondence, observed that Mr. Hunter had called attention to the dredgings in the Manchester Ship Canal, and it was certainly disappointing to find that the reduction of solid matter discharged into the rivers had not been of more material benefit to the Ship Canal Company. That a vast quantity of cinders and solid refuse derived from sewage and manufacturing works was kept out of the rivers was proved by the accumulations run to spoil which were visible in all parts of the watershed. Moreover, the evidence of owners of mill-reservoirs on the rivers was to the effect that their dams were not silted up to anything like the extent they used to be. With regard to sewage-matter, Manchester alone sent to sea nearly 200,000 tons of sludge a year. When to this was added the solids kept out by other local authorities and by manufacturers, without, according to Mr. Hunter's figures, making any material reduction in the amount of dredgings, the conclusion was reached that the results of the efforts of the joint committee to purify the rivers could not

be correctly judged by the figures put forward, figures which, in the Author's opinion, seemed to show that no substantial reduction of the amount of dredging would accrue, and consequently that the cost of dredging would continue to be a large one. The statement that "the material dredged consisted largely of manufacturers' refuse and sewage-sludge" was not borne out by chemical analysis of the dredgings, which showed that even in the protracted drought of last summer, to which Mr. Hunter referred, the proportion of mineral matter to organic matter varied between 3 to 1 and 4·7 to 1. In ordinary weather, with a larger flow, the proportion of mineral matter was much higher, the fine mud in the dredgings being only 3 per cent. of the whole. Protection of the banks of the rivers from the erosive action of the stream was the only sure remedy, and it was satisfactory to note that the Company had done something in this direction on the Mersey. The Author could not agree that had the Ship Canal works never been constructed the rivers and streams in the watershed of the Mersey would have been left in their foul condition. The work of purification was no doubt made more urgent by reason of the impounding of the water, and to Sir John Hibbert was due the credit of foreseeing a means of dealing with the pollution in a better way than it had been previously dealt with, namely, by forming a Joint Committee representing all the administrative authorities in the watershed. The fact that river-boards for the prevention of pollution had been established on the River Ribble and in the West Riding of Yorkshire, and that in other parts of the country the question was receiving serious attention, showed that, not only in Lancashire and Cheshire but in the country generally, the feeling was that pollution of the rivers should be put a stop to. Mr. Malcolm Paterson had called attention to the difficulty of treating waste from the wool-scouring processes. This waste did no doubt require special treatment, but there were works in the watershed where it was successfully dealt with. The concentrated liquors containing the animal oil and soap had to be treated in the first instance with acid and the oils recovered. If this were efficiently done the return from the recovered oils would go a long way towards paying for the cost of treatment. The process differed slightly from that of Messrs. Kelsall and Kemp, but if wool-scouring were carried on at their works there was no reason to think that the method of treatment would require any material alteration. If the trade-waste from wool-scouring and dyeing processes was subjected to a preliminary treatment which removed the bulk of the solids and of the grease and rendered the

Mr. Tatton.

Mr. Tatton. effluent neutral, the Author was of opinion that it might be admitted into sewers, but this should only be allowed in cases where the manufacturer had not space enough on his own premises to put down efficient works.

Mr. Meade-King. Mr. MEADE-KING, in reply to the Correspondence, remarked that it was gratifying to see Mr. W. H. Hunter alluding to the effect produced on impure liquids by salt water. In a Paper[1] recently read by the Author before the Society of Arts he had expressed the opinion, in regard to the question of the advisability of places, large towns in particular, draining into tidal waters without previous purification, or, at any rate, partial purification of the sewage, that the correctness of such a method of sewage-disposal was exceedingly doubtful. The fact that salt water acted, as it undoubtedly did, as a precipitant, was one of his chief reasons for coming to this conclusion. After the experiments recorded had been tried and the Paper written, the Author was informed in the course of conversation that the late Dr. Angus Smith had at one time been called in to report on the navigation of the Clyde and the silting up of the river, and that, after much investigation, he had given it as his opinion that the salt water in the Clyde acted on the Glasgow sewage, which was discharged untreated into the tidal waters of the river, as a precipitant, and was the principal cause of the silt complained of. Inquiries had been made to see if such a report could be traced, but so far unsuccessfully. If it were a fact, however, it would bear out the experiments mentioned in the Paper. Further inquiries had been made at places situated on the coast, and in some cases the action of sea-water on the sewage discharged had been observed, when it was found to bear out the experiments.

Mr. Paterson's first question as to the composition of the salt water had been previously answered in replying to Mr. Baldwin Latham. In answer to his second question, as to what mechanical method of stirring should be adopted, a simple one that presented itself to the Author's mind at the moment was the one generally employed in mixing lime at works where the latter was used as a precipitant, but doubtless numerous methods would present themselves according to the circumstances of the case. Of course mixing might be, and generally was done, by baffle plates in a mixing race leading to the tank, but with the means at the Author's disposal and the quantity of liquid he had to deal with, it was not practicable to adopt this method; nevertheless he was of opinion that

[1] Journal of the Society of Arts, vol. xlviii., p. 201.

stirring in bulk might have a better effect than the means usually adopted. So far as the desirability of quiescence in the liquid in the tank was concerned, the Author was strongly of opinion that wherever it could be obtained three continuous upward-flow tanks should be provided, which would secure comparative quiescence in the last two tanks. The stirring in the first tank need not be continuous. The filtering of tank-effluents from woollen-trades might only be of secondary importance when compared with the importance of previous precipitation, but filtration in all cases, woollen-trades not excepted, was a necessary process for purification. Mr. Meade-King.

16 January, 1900.

SIR DOUGLAS FOX, President,
in the Chair.

The Discussion upon the Papers by Messrs. Tatton and Meade-King on "The Purification of Water after its Use in Manufactories" and "Experiments on the Purification of Waste Water from Factories" occupied the evening.

23 January, 1900.

SIR DOUGLAS FOX, President,
in the Chair.

(*Paper No. 3203.*)

"Swing-Bridges over the River Weaver at Northwich."

By JOHN ARTHUR SANER, M. Inst. C.E.

THE River Weaver forms the great waterway of Cheshire, serving the salt- and alkali-industries and through traffic to and from the potteries by way of the Anderton Lift. Although the length of the canalized portion is only 20 miles, a very large traffic is carried on by means of barges of capacities varying between 25 tons and 350 tons; their size being only limited by that of the locks, which are 220 feet by 42 feet 6 inches, the navigable depth of the river, 10 feet 6 inches, and the headway under the bridges. On the completion of the works described in this Paper the minimum headway will be 55 feet, with one exception, the Hartford rural-road bridge; every effort is, however, being made to secure its removal, and thereby to complete the scheme inaugurated in 1865, to make the river available for small coasting vessels, and save in many cases the cost of transhipment at Liverpool.

In its course through the salt-districts the Weaver passes through the subsiding areas, and, with the exception of the Northwich bridges, all the permanent works have been removed, at great expense and after several extensive alterations, to firm and sound ground. The Northwich bridge would have been removed to a better site long ago, but it forms a portion of the main road (the Roman Watling Street) from Chester to Manchester, with valuable property on both sides of the river, and the vested interests are so great as to preclude any idea of diversion. For many years this bridge, which was a plate-girder structure of 90 feet span, had caused, owing to the subsidence of the district, great inconvenience to the river-traffic through the constantly decreasing headway. The average yearly loss of headway for about 16 years has been

4½ inches in the locality of this bridge, so that the house property is about 6 feet nearer the water-level than formerly. It was imperative to maintain the full headway for present traffic; the Author and his predecessors in the office of engineer to the Weaver Trustees, had accordingly from time to time raised the girders. The streets in the immediate neighbourhood could not, however, be raised in a corresponding manner without partially burying or raising the adjoining houses, so that the road-gradients became as steep as 1 in 11. It was also desirable, in view of coasting vessels with fixed masts using the river, to do away if possible with any form of fixed bridge.

The problem of erecting an opening bridge on such a site was no easy one, and among the existing forms of movable bridges the Author was unable to find a type exactly suitable to the case. The main points to be secured were:—(1) The sectional area of the river must not be unduly diminished; no central pier was therefore admissible, as widening the river—owing to the value of the adjoining property—was not possible. (2) A continuous towing-path must be provided. (3) The subsiding ground necessitated a form of structure easily adjustable. (4) The structure must allow for floods, drought and ice. (5) There must be as little interference as possible with the road-traffic, as, apart from the fact of the bridge forming part of the main road between Chester and Manchester, there was no other bridge across the river within 2 miles in each direction. The fifth point was provided for in the Weaver Act of 1893 by Parliamentary powers being granted to the trustees for the erection of two swing-bridges, some distance apart, so that one bridge could always be available for road-traffic. The second point was overcome by making the long end of the swinging portion span the towing-path as well as the river: this caused the tail end to be somewhat shorter than the usual practice. The sectional area of the waterway was preserved as far as possible by carrying the towing-path on open piling and lengthening the span to the extreme limit.

The form of bridge finally adopted by the Author is shown in Figs. 1, Plate 2, and consists essentially of:—(1) A pair of bowstring lattice girders carrying the road and footways. (2) A sealed circular pontoon or buoy, placed under the centre of gravity of the superstructure, and suitably and rigidly connected thereto, in such a manner as to be always submerged in the river, and capable of being turned with the superstructure. (3) A group of cast-iron screw-piles surrounding, but clear of, the pontoon, and carrying a gridiron girder, which in its turn carries the bottom

roller-path; cup-castings and adjustable screws are inserted between the heads of the piles and the girder.

The pontoon is placed under the centre of gravity of the superstructure, and is rigidly connected with it, so that it exerts an upward pressure equal to the buoyancy due to its displacement; the pressure is, however, less than the aggregate weight of the superstructure and connections by a quantity which can be varied at will within certain limits. The remainder of the weight of the superstructure rests on the roller-paths, and is conveyed by the gridiron girder to the piles and thence to the ground. For example, if the total weight of the superstructure, connecting girders and shell of pontoon is 303 tons, and the normal buoyancy of the pontoon 255 tons, the weight remaining on the rollers and piles is 303 tons − 255 tons = 48 tons. In the event of adjustment being required, therefore, instead of 303 tons only 48 tons have to be dealt with, and even this can be reduced to 28 tons by emptying the upper part of the pontoons. The pile-heads are fitted with screws by which the gridiron girder can be raised or lowered, so that a daily adjustment can be effected if required—a by no means improbable contingency. The pontoon acts as a low-pressure hydraulic ram, and not only facilitates adjustment but materially reduces the friction on the rollers when turning.

In order to put the principle to a practical test, the Author obtained in 1893 the sanction of the Weaver Trustees to convert one of the numerous occupation bridges on the Navigation which was undergoing alterations. Although intended for cattle-traffic only, the bridge was double-ended, 10 feet wide, 92 feet long, and spanned two 40-foot openings. By placing the empty shell of an old boiler under the centre of gravity, the friction on the rollers was so reduced that one man could turn it through 90° in 30 seconds, but on partially filling the pontoon with water it soon became impossible for two men to move it. The result was very satisfactory; and the bridge—which was completed early in 1893—continuing to work freely and well, and to require only ordinary attention, it was determined to erect the much larger and more important works described in this Paper.

The pontoon, Fig. 5, Plate 2, both of the experimental and new bridges, has a watertight deck situated about 1 foot below normal water-level. The portion above this deck is open to the river through scuppers provided with valves, so that the water rises and falls according to flood or drought; the portion below

this deck is, however, empty and sealed, and has, consequently, a constant buoyancy whatever the level of the water outside, provided such level does not fall more than 1 foot below the normal. There is no danger, therefore, of the bridge being lifted off its seatings. In the new bridges the pontoon is surrounded by a casing of timber piling, and can be entirely covered in during severe frost, though no trouble has hitherto been experienced from ice at the experimental bridge, it having been always found possible to break it away as it is formed. The timber screen serves, however, the additional purpose of keeping sand and detritus from collecting under and around the pontoon.

It was at first intended to depend entirely on manual labour for the several movements in connection with swinging; but, owing to the increase of weight necessitated by the requirements of the Act of Parliament, it was decided to provide additional gearing, actuated by power. There again arose the difficulty of subsidence, and the Author decided, after considering the different powers at his disposal, viz., gas, steam, hydraulic pressure and electricity, to adopt the last named, although, so far as he was aware, it had not previously been used for the purpose of bridge-turning in England. This power appeared to the Author to be eminently suitable under the circumstances, the cables not being liable to breakage, as would be the pipes required for any of the other powers. It was therefore decided to adopt motor-driven gearing not only for the swinging-motion but also for the withdrawal of the wedge-blocks upon which the ends of the bridge rest when across the river.

When the bridge is open for river-traffic, "safety" gates, Figs. 8 and 9, Plate 3, are closed at each end. These gates, with the exception of the two at the tail end of the Town Bridge, the more northerly of the two new bridges, are moved by hand; as it was feared that, if moved by machinery, they might prove a source of danger to passengers who happened to be within reach and not on the alert at the time of closing. The bolts fastening these gates open are so arranged that the bridge cannot be swung until they are withdrawn. The swinging gates, which weigh about 31 cwt. each, are hung on a circular ball-bearing at the top of the centre column and are connected by a cross shaft and quadrants under the roadway; they can be easily closed or opened with one hand. The tail-end gates for the Town Bridge are shown in Figs. 8, Plate 3, and are moved by two 4-B.HP. electro-motors controlled by a switch placed near the cabin-door, in order that the man in

charge can warn anyone in the way. The two bridges were built from the same drawings, and as the only difference is that one gives a clear headway of 16 feet at normal water-level, and the other 10 feet, the same description will suffice for both.

The abutments of the second or south bridge, now called Navigation Bridge, had to be commenced *de novo*, but in the case of the Town Bridge, the old abutment on one side was made use of. The abutments and pontoon chambers, as will be seen from Fig. 1, Plate 2, consist of short compact concrete and masonry walls, built with broad bases and tied through with chain-cables so as to form as solid and homogeneous a mass as possible. The amount of concrete and masonry was kept at a minimum, as experience shows that, however strongly they may be built, they are liable to destruction by subsidence. The remaining portions, including the whole of the pontoon-chamber and tail-end abutment of the Town Bridge, together with the towing-paths and protection-works, are constructed chiefly of timber. Where necessary, the piles are V-grooved—a form which the Author has used largely elsewhere on the Weaver with very satisfactory results.

Pontoon-Chamber.—Considerable difficulty was experienced in preparing the pontoon-chamber for the Navigation Bridge owing to the great depth of fine wet sand, but it was finally excavated to the required depth of 15 feet below normal water-level. The concrete wall was inserted in short lengths, each length being surrounded by grooved piles and excavated by means of a grab dredger, as it was found impossible to pump the foundation dry. On the required depth being reached, the concrete was lowered in bags or by means of a drop-bottom box. In computing the stability of the wall, allowance was made for its being surrounded with water, and it was made of sufficient weight to resist the pressure of the earth, although nearly submerged. To relieve the pressure on the inner wall, a fixed span about 29 feet 3 inches long, supported on wrought-iron columns at the bridge end, and a second retaining-wall at the shore end, were built. This second wall was founded on a stiff bed of clay, and was given a very broad base. In the case of the Town Bridge, a puddled cofferdam was constructed to enclose the old abutment, which was easily and successfully removed and the new work was substituted for it. Chain-cables of $\frac{3}{4}$-inch and 1-inch iron were embedded in all the concrete walls to give lateral strength.

Screw-Piles.—The next operation in each case was to screw in

the cast-iron piles, Figs. 6, Plate 2. These are 2 feet 6 inches in diameter, $1\frac{3}{4}$ inch thick, and in lengths of 10 feet, the screw-blade being 4 feet 6 inches in diameter, and having a pitch of 10 inches; the lower end of the pile is provided with a serrated edge. There are ten piles at the Navigation Bridge, and seven at the Town Bridge surrounding the pontoons, and there are three similar piles 1 foot 6 inches diameter carrying the receiving girder for the nose end of each bridge. These were all screwed into the ground 26 feet below water-level, and were then filled with cement concrete. At times the progress was so slow as to be only $\frac{1}{8}$ inch per revolution, one revolution occupying an hour in the case of the larger piles. This rate of progress was, however, increased to as much as 4 inches per revolution by using a water-jet introduced by means of a pipe down the centre of the pile. It was found that those piles in which the jet had been used were entirely emptied of sand, so that there was nothing to prevent their being properly filled with concrete. It was computed that in the very unlikely event of the entire failure of the pontoon, the greatest pressure on any one pile would not exceed 4·6 tons per square foot, provided the blades of the screw remained intact.

Pontoons.—The pontoon for each bridge is made in four quadrant-shaped pieces, Figs. 1 and 5, Plate 2, forming together a circular buoy 30 feet in diameter and 12 feet 6 inches in depth from the upper deck to the dished bottom. The four pieces are placed 6 inches apart, and are connected at the top by a circular girder, D, riveted to the upper edge of what may be termed a "bulwark" rising 2 feet 6 inches above the deck, and 1 foot 6 inches above water-level. This girder is provided with horizontal wheels, which would come in contact with a second circular girder, E, should there be any severe displacement of the structure whilst turning. The girder E also forms a bracing for the cast-iron piles. The plating of the pontoons is $\frac{3}{8}$-inch steel, with 3-inch by 3-inch by $\frac{3}{8}$-inch angle-iron frames, and the flat vertical sides are stiffened with vertical gussets. The bottom is dished, and the deck is flat, being provided with manholes and valves for regulating the water. At each bridge a double-action hand-pump is fixed for keeping the pontoon clear of water. All the pontoons were tested before launching by being filled with water, and so far have proved perfectly tight.

Connecting Girders.—The connections between the pontoon and the superstructure are shown in Figs. 2, Plate 2. The carrier-

girders, A, B, are double-web box-girders, built of ½-inch plates, and stiffened with angle-bars and gussets. The whole upward pressure of the pontoon is by this means concentrated under the six central verticals of the superstructure, the two central verticals bearing 46·9 tons each, and the four others 23·45 tons each.

Superstructure.—The superstructure consists of two braced girders 112 feet long, with a cambered top boom, the height over the centre of gravity being 17 feet. The roadway, which is 19 feet 6 inches wide, is placed between the main girders, and consists of steel trough-flooring covered with oak planking, laid on felt to deaden sound. The footways are of oak planking 4 feet 6 inches in clear width, and are carried outside the main girders by cantilevers.

Rollers and Paths.—A circular box-girder, F, Figs. 1, 2 feet deep and 27 feet 6 inches in external diameter, is fixed to the underside of the lower boom and distributes the weight to the upper portion of the cast-iron roller-path. This in turn rests on a live ring of seventy-two conical rollers, each provided with an internal flange, as shown in Fig. 3, Plate 2. The rollers and lower roller-path are carried by girder G, a star or gridiron-shaped girder 2 feet deep and shaped in plan as shown in Fig. 4, Plate 2. Each ray of the star has a hemispherical cast-iron foot which fits into a corresponding steel socket of somewhat larger radius, Fig. 7, and forms the head of the pile. Each of these cast-steel sockets is fixed on four screws, 4½ inches in diameter, passing through bosses on the top length of pile, and adjustable vertically by means of nuts. Should, therefore, the girder G, with its roller-path, subside, owing to the subsidence of the piles, it is only necessary to adjust the screws; and eventually, when the screws are fully out, to insert a fresh short length of pile under the top casting.

End Girders and Wedges.—The ends of the bridge when across the river are carried on wedge-blocks fixed to substantial box-girders resting on the cast-iron piles, in order that the whole piece may be adjusted for level as required. The circular end-pieces on the swinging portion are finished off with cast-iron, but on the shore are oak planks, in order that any "jamming" may at once be alleviated by cutting away the timber.

Hand-Turning and Wedge-Drawing Gear.—By means of a simple rack-and-gearing arrangement, partly shown in Fig. 3, Plate 2, the bridge can be swung by one man in about 4 minutes on a calm day. It would be necessary, however, in case of the electric power being off at the time of a high wind, to have additional

assistance. The wedges can also be actuated by hand, a hand-wheel being first fixed on the vertical shaft,[1] Fig. 14, Plate 3.

Electrical Installation.—The most convenient supply of electricity was to be obtained from the Northwich Electric Supply Company, whose installation consists of three 100-HP. Crossley gas-engines, driven by Mond producer-gas,[2] and an arrangement was made to take current from their three-wire system, at 440 volts for the motors, and at 220 volts for lighting purposes. The present charge is 4*d.* per Board-of-Trade unit for both power and light.

Wedge-Gearing.—As before stated, the superstructure when at rest across the river is kept in position by means of two pairs of wedge-blocks placed on cross-girders H and J, Figs. 1, Plate 2, supported by the screw-piles, which also retain the fixed shore spans. These wedges are actuated by 4-B.HP. electric motors, and are pushed home from the centre line outwards; they have a rise of 1 in 1½, and when withdrawn give a clearance of 3 inches. The speed of the motors is 1,100 revolutions per minute, reduced by gearing and screws until the total stroke of 24 inches is made in 10 seconds, Figs. 14.

Turning-Gear.—The total weight of the mass to be revolved is 303 tons, 255 tons of which is supported by water; in addition, the area of the surfaces exposed to the wind is 695 square feet on each girder, and allowing 40 lbs. per square foot as a maximum wind-pressure, the Author concluded that to insure the bridge being under control in all conditions of weather, and turning within the limits of time allowed by the Act of Parliament, a 20-B.HP. motor should be provided. To prevent as much as possible interference from subsidence, the motor and gearing, Fig. 10, Plate 3, were connected with a heavy cast-iron bed-plate, and bolted down to a monolith of concrete. Instead of direct connection between the machinery and bridge, the power is transmitted by two 1½-inch wire-ropes, wound opposite ways round a vertical barrel, and fixed to the circular girder F, Figs. 1, Plate 2. In this manner one rope pays out while the

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[1] At a special trial made for the purposes of this description one man opened the Navigation Bridge in 3 minutes; he only managed to get it back about half-way, however, as there was a light breeze from the south. Two men then assisted him, and the whole movement of the bridge occupied 7 minutes 15 seconds. There are 95 turns of the handle each way. The complete operation, by hand-power only, of closing the gates, withdrawing the wedges, swinging the bridge, replacing the wedges and opening the gates again to road-traffic, occupied 8 minutes 50 seconds. This was done twice.

[2] Minutes of Proceedings Inst. C.E., vol. cxxix. p. 190.

other is being wound up, and the bridge is practically under the same control as if two hydraulic rams were used. The ends of the ropes pass through clips, and can be easily adjusted for length. To obviate friction as far as possible, the weight of the vertical drum is carried on a ring of 1-inch steel balls placed between two Whitworth compressed-steel plates, and the thrust of the worm on the motor-shaft is also taken by ball thrust-bearings. The benefit of these bearings is obvious, as it is possible to revolve the gearing when without load by gripping the motor-shaft in the hand, although the total weight of the gearing and armature is about 50 cwt. The actual weight of the spur-wheel drum and shaft, Fig. 10, Plate 3, is 31 cwt. The bridge is brought to rest by means of a check-chain, attached to the tail end and to the concrete wall in such a manner as to stop the bridge in the correct position both ways. A dial in the switch-cabin shows the actual position of the bridge, and is useful at night-time. Owing to its being necessary to have the interior of the cabin well lighted at night in order to see the ammeters, and therefore very difficult to see the exact position of the bridge, a small lamp is fixed on the tail end in such a way that the light, shining through a vertical slit, coincides with two vertical rods when the bridge is in position, somewhat on the principle of the cross staff.

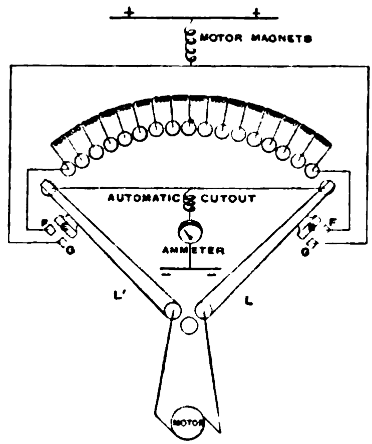
Lighting.—Each bridge is provided with a 2½-ampere Stewart arc-lamp at each end, and 16-candle-power incandescent lamps for use after midnight. The switch-cabin is also lighted electrically, but is heated by ordinary gas supplied by the local gas-company.

Switch-Cabin.—All the switches are arranged in a wood cabin fixed over the turning-gear, and by means of numerous windows the attendant has a full view of everything, as well as full control. One of the most important points in connection with the electrical installation was the circuit-breaking, and a most ingenious arrangement of switch was devised by Messrs. Mather and Platt to prevent injury to the motors. The main idea was to so arrange the switches that nothing short of wilful neglect on the part of the attendant could cause an accident; the points to be met were briefly as follows:—(*a*) The power must not be applied too suddenly. (*b*) Any increase of current beyond the safe limit must be immediately checked. (*c*) There must be some indication when the motions, more especially of the wedges, are complete. (*d*) The switches must be simple in action and arrangement so that men of ordinary intelligence can manipulate and keep them in order. (*e*) They must reverse. The essentially novel points in connection with their construction are:—(i) Automatic

disconnection in case of a too-sudden load or an over-load. (ii) There is only one moving contact for each motion. (iii) The same set of resistance-terminals acts for both opening and closing motions of the motors.

The arrangement is shown in Figs. 11, Plate 3, and *Fig. 15*, and consists of two radial contact levers, L L′, being caught up as required by the third lever, *b*, which has a spring catch similar in action to a railway signal-lever. This lever, *b*, is of course insulated from the contact levers which form part of the circuit. To open, the lever L is caught up and moved through the resistances, while L′ remains in position and forms part of the circuit; to close, lever L′ is moved and L left in normal position. Should either of the levers be pushed too far over, the spring-catch would release itself and the lever fly back to normal. It will be easily seen that although the main motor for turning the bridge can be started slowly and stopped slowly through resistances, that is not the case with the motors driving the wedges. The wedges and their motors being under the bridge are out of sight of the attendant, and it was therefore essential for everything to be automatic; this is accomplished as follows:—In the first place, the motors are allowed to start without any load by means of slots in the connecting links, but as soon as the nut of the actuating screw reaches the end of the slot, full load is obliged to come on until the wedge is released, when it again falls to a minimum. On returning the wedges all is light load until the last push, but as the final position of the wedges is slightly variable owing to subsidence or temperature, it is impossible to know when to break circuit unless the ammeter is carefully watched, and even then sometimes before the man can disengage, the current has risen abnormally to perhaps 25 volts or 30 volts. The whole operation of withdrawal or return only takes 10 seconds, so that prompt attention is necessary. In order to give as much warning as possible, spring-buffers have been fixed, which gradually increase the resistance and warn the attendant; but should he not be in

Fig. 15.



time, an automatic cut-off has been arranged so as to disengage the switch on a certain limit of current being reached. This arrangement consists, Figs. 11, Plate 3, of a pair of solenoid coils fitted with plungers connected to a cross-bar and spring A. The cross-bar is connected by means of a piece of flexible wire to the disengaging lever, *b*, and on a current of 30 amperes (about three times the normal load) passing through the circuit, the plungers are attracted and disengage the secondary radial lever, L, from the hand-lever; the counterweight, W, then causes the secondary radial lever, L, to fall through the resistances to zero. In this manner there is ample protection to the motor whether the attendant is on the alert or not. The solenoids are connected in a "shunt" circuit. In order to minimise the danger of a too sudden application of the load, it was thought well to make a substantial lever and counterweight; the attendant has, therefore, to do a slight amount of physical work, and is reminded of the forces which are being set in motion by his action.

The Navigation Bridge has up to the time of writing been opened and closed 155 times, and at a test opening it was turned through the required arc of 80° in 45 seconds; as a rule, the gates can be closed, wedges withdrawn, and bridge turned in 1½ minutes, although by the Act of Parliament 1½ minutes was the time given for turning the bridge only, without the other movements. The amount of electric current used for the complete operations of opening and closing, including the wedge-motions, is one quarter of a Board-of-Trade unit, costing 1*d*. This figure is taken from the Aron meter put in by the Supply Company, and does not appear to vary, as it is found that although more power is required during a high wind for moving in one direction, less is required for the reverse direction, as the wind assists. The attendance of one man and a youth is required by day and by night.

Cost.—The cost of the undertaking was largely increased by the construction of 363 yards of new streets, rendered necessary by the condition that two bridges should be provided, *Fig. 16*. The gas- and water-mains crossed the old bridge, and as it was not considered safe to rely on a single siphon under the river in such treacherous ground, Parliament decreed a second pair of siphons near the site of the second bridge and their connection with existing mains by new mains along the new streets and across the River Dane (a tributary of the Weaver) to points suitable for connection with the existing pipe-lines. In the case of the gas, the new main measures 732 yards of 8 inches in diameter, and the new water-main measures 1,227 yards of 10 inches diameter. The new streets

are 36 feet wide, and are well constructed with Yorkshire-flag pavements, macadamized roadway, and stoneware drains; the pipe-lines are of full strength and are provided at intervals with long thimble-joints to allow for stretching, due to subsidence of the ground; all the joints of the water-pipes have rings bolted on, in order to prevent the lead from being drawn out while stretching. The siphons under the river consist of welded and flanged steel tubes, jointed with rubber rings and tightly bolted together. The first cost of the bridges can scarcely be compared with that of others built on sound ground; every detail had to be designed to meet the peculiar circumstances and to prevent as far as possible any heavy maintenance-costs. So far as the cost of attendance and of power for

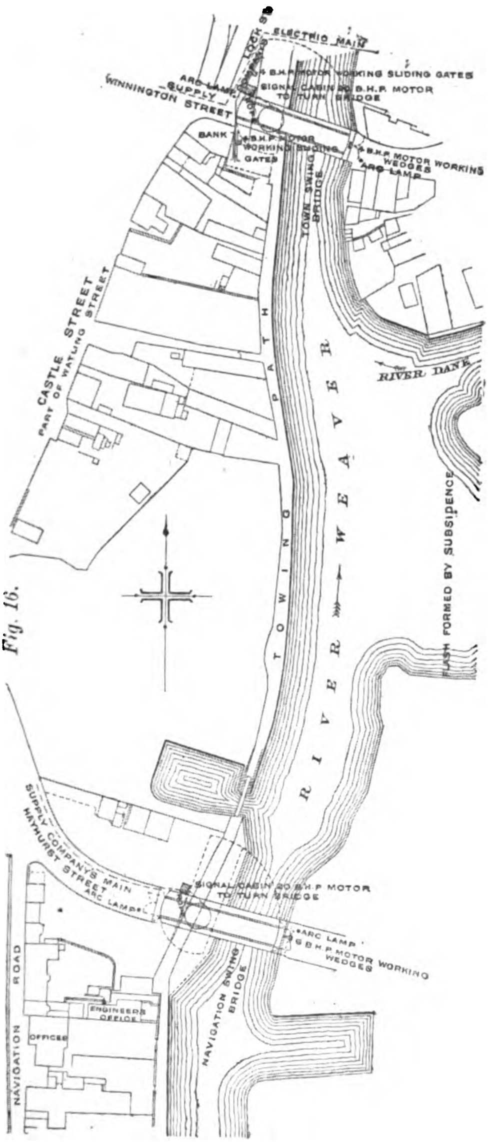


Fig. 16.

Scale, 1 inch = 200 feet.

SITE OF THE WEAVER NAVIGATION SWING-BRIDGES, NORTHWICH.

operating is concerned, this seems to have been accomplished; in the case of the adjustments only time will show; the Author has, however, no doubt of the soundness of the principle adopted. Future bridges on the same principle, but erected on sound ground, could certainly be built more cheaply, but the total cost of the two described is:—Navigation Bridge, including fixed spans, but exclusive of roads and pipes and foundations, £9,031; and Town Bridge, £7,904, the price of material and labour being now considerably higher than it was a few years ago. The electric machinery, etc., cost an additional £1,100 for each bridge.

The foundations, timber piling, concreting, excavations, etc., were carried out by the Trustees' own men under the Author's direction, but the electrical plant and iron and steel work were let by contract, and the Author desires to express his appreciation of the manner in which the contractors rendered him assistance in overcoming difficulties of detail arising in the execution of the work. The late Mr. Thomas Hawksley was joint engineer with the Author in obtaining Parliamentary powers, the scheme being strongly supported by Sir Benjamin Baker. The Author is also indebted to Mr. John J. Webster, M. Inst. C.E., for his suggestion of the pontoon-principle and his assistance when the original designs and models were made in 1893.

The Paper is accompanied by sixteen drawings, from which Plates 2 and 3, and the Figures in the text have been prepared.

Discussion.

The PRESIDENT said the members had been listening to a very practical communication, dealing with what he thought was always interesting to engineers, the adaptation of a design to special circumstances. Those who had experience of the effects produced upon superstructures or upon the beds of canals, and of other damage caused by subsidence, could well realise that the problem before the engineer in the case under consideration was not a simple one; and he thought the members would agree with his view that the way in which it had been solved by the adoption of a floating pontoon was one very worthy of praise. It seemed a simple mode, after all, of dealing with what was apparently a serious difficulty. He was sure the members would join in passing a very hearty vote of thanks to the Author for his communication. The President

Mr. J. A. SANER thanked the members for the vote they had passed to him. The work had been one of the greatest interest to himself for the last two or three years, and he felt certain that the plan adopted was one which might be used on other occasions with advantage. He would like to add that, since writing the Paper, the town bridge at Northwich had been turned, up to midnight on the 6th January, 303 times; and that, exclusive of current used for the tail gates but inclusive of current used for trials for the wedges, 97 Board of Trade units had been consumed, as recorded by the Aron meter. The quantity now required was less than at first, and for the last fifty-three times had averaged 0·226 unit each time, for the complete cycle of operations mentioned in the Paper. As a check on the Aron meter, he used one of Elliott's recording ammeters, and the result of a trial with that ammeter was shown in the diagram (*Fig. 17*). The first movement showed the opening of the wedge at the nose end of the bridge. The second movement was a similar opening of the wedge at the tail end. The curve showed the opening of the bridge, which occupied 50 seconds. There was then an interval of 152½ seconds, during the time the barges passed through, and the next curve marked was the closing curve, which was somewhat long on account of a barge in tow being in the way. The little excrescence just beyond the end of this curve showed that the bridge was not quite home, and that the man Mr. Saner.

Mr. Saner. had had to put on the current again momentarily. The tail end of the wedge was then put in, and the nose end followed. Working out the area of the diagram, the power consumed was found to be 0·2313 unit, the average rate of working of the motors being about 6 HP. That, compared with the 0·226 unit obtained as the average of fifty-three trials by the Aron meter, fairly well satisfied him that the Aron meter was recording properly.

Mr. Saner then exhibited some slides, illustrating the progress of the work.

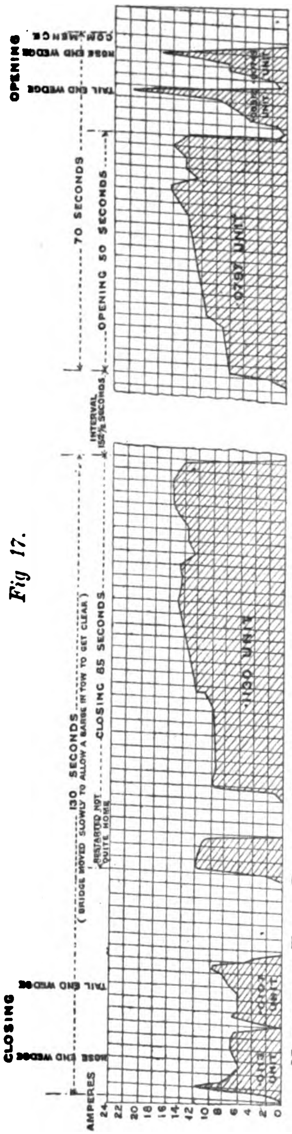


Fig 17.

Northwich Town Bridge.—Recording-Ammeter Diagram taken 30 December, 1899. Southerly Wind, Fresh and Gusty. Total Power consumed = 0 2313 B.T. Unit.

Mr. Robertson. Mr. F. E. Robertson said the solution of the problem appeared to him to be simple and perfect, and he had no criticism whatever to offer on it. The only remark he had to make was that, considering the very uncertain nature of the strata—both the central pivot and the abutments floating round, or worse still, constantly subsiding—he presumed a very careful watch would be kept on the end reactions of the bridge. He supposed it would be impossible to predict whether the abutments, either or both, or the central pivot would be likely to sink first. That had been provided for in the very ingenious arrangement carrying the roller-ring. He hoped that somebody might find some suggestion to offer, but he had only one remark to make apropos of swing-bridges. He once had to deal with a railway swing-bridge designed and erected by a foreign firm. Instead of using a live ring they had employed fixed rollers, which were an utter

failure. There was the greatest difficulty in turning the bridge, and the turning-gear wrenched itself to pieces. It was supposed to be turned by four men at the winch, but that was not possible. When men enough were put on, everything began to go, the teeth of the rack chipped, and the consequence was that one of the shafts twisted itself to pieces. The rollers were ordinary fixed rollers in trunnions, and he presumed there was a difficulty in getting them to take their proper share of the bearing; but if anyone should think of trying that arrangement he could, from experience, warn him against it. Mr. Robertson.

Mr. MAX AM ENDE also thought the arrangement of a semi-pontoon bridge described in the Paper very ingenious, and admirably suited to the case. He believed similar arrangements had been proposed, but, to his knowledge, never carried out. It could hardly be compared to a floating bridge, where the nose end rested on a pontoon, the pontoon was floated out, and the bridge was swung round a pivot on a fixed pontoon. That arrangement had been carried out, he believed, in two or three cases, one being at Aalborg, in Denmark. The arrangement of the girders transmitting the weight of the bridge to the pontoons and the columns was also ingenious, and not open to much criticism. But if the arrangement of piles or columns surrounding pontoons or a fixed pivot should be applied to other cases of larger dimensions, it might be interesting to inquire whether, instead of the seven piles, it would not be better to have only three, and connect them by means of three straight girders, forming an equilateral triangle in plan. With a few additions, in order to provide for the roller path, they would, so far as he could see, replace the girders E and G together, and the stresses which in that rather complicated arrangement of girders would occur from the subsidence of one of the piles would be entirely avoided, because the subsidence of one of three piles would not make any change in the stresses. Such an arrangement would also have the advantage of allowing the floating out of the pontoons for repairs that might be necessary from time to time, which he thought was not possible in the Author's case, as there was no room. In that case, he thought, instead of four pontoons there should be six, so that, if two were floated out, a third of the 255 tons would come upon the three straight girders and upon the piles. That weight, amounting to an additional pressure of 28 tons on each girder, would not be a difficult matter to deal with. With regard to the roller-arrangements, he had no remark to make, but he might perhaps say a word about the main girder. It was of a fairly correct shape. It was pointed Mr. Max am Ende.

Mr. Max am Ende. at the nose end, the top member was horizontal over the piers and went down where the counter-balance weights were placed and where also was an upward pressure. A curved member connecting the points of triangulation might perhaps be objected to, because it was well known that stresses between such points went in straight lines and not in a curve; but when the stresses were not very great, as was the case with the bridge under discussion, the taste of the designer had certainly some weight, and within certain limits he might do as he liked. Moreover, the curved member was easier to design and to make than a polygon, and the connections were easier. But then there was the question of balancing the wind-pressure which was alluded to in the Paper. In a similar case he once proposed to make the top flange horizontal from the middle of the pier to the end, and to make the last panel a wind-screen, which would balance, he thought, the wind-surface on the other side. There would be at the end of the bridge a portal which might retain the whole of the balance-weight in a very much better position than where it was now. But that proposal was objected to because it was unusual, and objectionable in appearance; a screen might be put up if required. However, in all matters of iron construction—he might say iron architecture—he had found that taste accommodated itself to the unusual and gradually came to tolerate novelties of form when the reason for the innovation became recognised; and that therefore utility was the safest guide in designing, but perhaps not the only guide.

Mr. Bell. Mr. J. R. Bell thought the members were unanimous in thinking that the work had been treated in a masterly manner. There were numerous small difficulties, nearly every one of which had been carefully gone into and overcome. As to some of the details about which his mind was less clear, it did not appear from the diagram that the main girder was counterbraced as he would like to see it. He conceived it was possible that the main group of seven or ten piles, as the case might be, might subside on some occasions without the tail or the abutment-piles subsiding. In that case the girder might, to the extent of 48 tons live-ring load, be left hanging. He had no doubt the girder would stand that and a great deal more with ease. Like the previous speaker, he had a predilection in favour of three-legged stools, both for the main pier and for the individual screw-jacks, and he thought that some plan which would allow of getting at the sections of pontoons symmetrically and in pairs, so as not to destroy the balance, would be very useful. He did not gather it from the Paper, but he presumed that the pontoons themselves were lined with brick

and cement after the manner of ships' bottoms, and that they were very stable indeed. Perhaps nothing less than a catastrophe would let the thing down and land the pontoons; but it was conceivable that siltage would take place underneath them and give trouble should any sinking occur. He would ask the Author to enlighten the members on another matter. Speaking as a layman in the matter of swing-bridges, it seemed to him that the wedges were perhaps a little short. Presumably they had to take up not only the sag of the girder, which might be something, but also, from time to time, sinkage that might approximate to 4½ inches at one or both ends of the bridge—assuming that it was possible for one of the supports to sink without the other. He did not know enough of Northwich to be able to say whether the ground did go down all in one or not. From some of the pictures the Author had exhibited on a recent occasion in the course of a discussion on subsidence due to coal-workings, showing houses and streets sinking in peculiar ways, he had the impression that a bridge might sink at one end and not at the other. He would also like the Author to say in what way he made provision for taking up pile-sinkage by the wedges, pending insertion of a new pile-length. He supposed the tail girder could not be lifted more than 4½ inches at a time. He would be very sorry, in the presence of so many experts, to enter into the question of electrical turning, but the Author seemed to have entirely eliminated the difficulties of worm-gearing, and to have turned the bridge very satisfactorily indeed by the simple expedient of putting in roller-bearings. Mr. Bell.

Mr. G. E. W. Cruttwell said the previous speakers had mentioned three-legged stools, but he would go a little farther, or rather not quite so far, and suggest a one-legged stool. He did not know whether the Author had ever considered it at all, but it had occurred to him that, possibly, instead of the seven piles, a single cylinder might be employed, which would be practically a one-legged stool, completely surrounding the pontoons, and thus a continuous support would be obtained for the rollers. He thought a cylinder of that depth, some 10 feet or more, would be pretty safe, and it would be bound to go down altogether. Of course, there would be the objection that the pontoons could not be removed in the usual way—as he imagined the pontoons shown could be removed—by shifting between the piles. They certainly could be removed in the case of the three-legged stool, but he thought in the one-legged stool they might be arranged so that they could be removed for repair by lifting them out through the top, or between the top of the cylinder and the under side of the Mr. Cruttwell.

Mr. Cruttwell. bridge in some way, instead of taking them through the sides of the cylinder. There would have to be a special design to enable that to be done, but he thought it was possible. The supporting power of the pontoons would be lost whilst they were being repaired, but that could be got over by making the surrounding cylinder act as a pontoon of itself by excluding the water from it. If the inner pontoon had to be repaired at any time the outer cylinder could be utilized as a pontoon. He would like to know whether anything of that sort was ever thought of by the Author.

Mr. Moir. Mr. E. W. MOIR asked the Author how he insured that the proper reaction was produced by the electrically-driven wedges. The real length of span was an important matter in a bridge like the one shown. The bridge was partially supported on three points, and was a continuous girder; and the reaction produced by the wedges was most important. In several swing-bridges for dock-works which he had seen erected by Messrs. Armstrong, and in a temporary one he had now working himself, the whole of the bridge was raised to swing, and set down upon the stools at a dead level, in which case the reaction was quite determinable; but in the case under discussion, it would appear to him that more or less greasiness or rustiness of the wedges might make a difference in their upward effort. The Author had also drawn attention to the fact that provision had been made for dealing with electrical energy exceeding the maximum required for driving the wedge home, which was evidence of a varying reaction. If one wedge took more power than the other it might lift the girder and increase the span. One speaker had called attention to the fact that there was no counterbracing; and it appeared to Mr. Moir that the span might virtually be the full distance between one set of wedges and the other, if more than the correct amount of energy was put upon the wedges in driving them home. He would like to know how the power put upon the wedges was controlled so that the upward reaction was correct.

Prof. Carus-Wilson. Professor CARUS-WILSON considered the Author was to be congratulated upon the boldness with which he had adapted electricity to the manipulation of the bridge. The Author had stated, and no doubt correctly, that he was the first to carry out on an extensive scale the application of electricity to the manipulation of such a bridge as that shown, over a canal or river. It might be of some interest to the members if Professor Carus-Wilson mentioned what he believed was the first instance in which electricity was used for similar purposes. It was in connection with the design of the lock on the Canadian side of the Sault St. Marie canal

connecting Lake Huron with Lake Superior. He was there in the year 1894, and at that time extensive experiments had been made on the Lower St. Lawrence at the lock at Beauharnois, with a view to ascertaining whether it was really practicable to use electricity for opening the lock-gates. Such satisfactory results had been obtained that it was decided to work all the gates and the valves at the new Sault St. Marie lock by electricity. This plan had been carried out and worked extremely well. The great gates, weighing 87 tons each, were opened in 50 seconds. The corresponding lock on the American side of the rapids was worked by hydraulic power, and he thought it was creditable to the enterprise of British engineers that they had adopted electricity. He would like to draw attention to the Author's statement that he had calculated that a motor of 20 HP. was needed to turn the bridge. No doubt the Author was right in allowing an ample margin of safety, but, at the same time, he might suggest that the Author should take advantage of the opportunity he now had to get some reliable data as to the real forces which had to be overcome in such a case. This was not a merely theoretical point; it was a very practical one, because there was a feeling among those who would employ electric motors that about twice as much power had to be used as would be required with any other kind of motor. Canadian importers of pumping machinery on a very large scale had informed him that they did not drive their pumps by electric motors because they were told they had to use more powerful electric motors than steam motors. They were told by the makers that an ordinary pump driven by a 10-HP. steam-engine would require a 20-HP. electric motor. As a matter of fact, there was far more certainty about the action of an electric motor than about that of a steam-motor. He thought, therefore, it was a pity that the Author had installed a 20-HP. motor for turning the bridge when, if Professor Carus-Wilson understood him correctly, the average power required was only 6 HP. After estimating the force required to open the bridge, he formed the opinion that the Author had put down far too large a motor. It seemed to him that the principle which was so often acted on was illustrated by an incident that occurred on a recent occasion at a well-known military academy, in which the students were asked to calculate the electric current required to explode a certain fuse. When they had calculated it to a fraction, the instructor said, "Now double it to make quite sure." Prof. Carus-Wilson.

Mr. W. MARRIOTT said the Paper was of a special interest to him, because he was at present engaged under Mr. Ross, the Chief Mr. Marriott.

Mr. Marriott Engineer of the Great Northern Railway, in putting up a swing-bridge for the Midland and Great Northern Joint Committee. Before getting out the plans he had made extensive inquiries to ascertain whether any electrical installation had been put up in the United Kingdom. He found that, as the Author stated, there was no electrical swing-bridge at all. He then obtained from friends in America particulars of many examples of electrical installations, including those of a drawbridge over Frankford Creek, Philadelphia, a drawbridge weighing 320 tons at Bridgeport, Conn., and a bridge for the Duluth Street Railway Company. He congratulated the Author upon being the first to bring the system into use in this country. Electricity had been under consideration for use with the bridge he had mentioned, but just at that time a very unfortunate mishap occurred with the Yarmouth electric light works, and the town was in darkness for a considerable time. He thought that had tended to put an end to the idea of using electricity for the bridge. He would like to ask the Author something about ball-bearings. Ball-bearings, in his experience, were very good servants but very bad masters, and he thought a great deal depended on how they were put in. He specially desired to know, as he was using them in several cases, whether the Author ran the balls in a V groove, as he understood was the modern way of running them, or whether he ran them in large U grooves. He had been told, and he believed it was the case, that on the Great Eastern Railway they were putting up some of the renewed swing-bridges with electrical installation.

Mr. Gilbert. Mr. W. GILBERT thought the adjusting apparatus was a little complicated. In the bridge shown in the diagram the girder G, carrying the lower roller-path, was supported by seven groups of adjusting screws, making twenty-eight screws in all. Apparently the girder G and the adjusting screws should be strong enough to carry the weight when three groups of screws only were in use, as, owing to slight settlement of the piles, the weight might come on three supports, although the flexible form given to girder G certainly tended to prevent that. But there seemed no reason for using more than three points of support, each over the centre of a short cross girder resting on two piles. Each set of adjusting screws might preferably be three in number instead of four, so that altogether there would be nine screws to carry the unbalanced load of 48 tons. To provide for possible failure of the pontoon, adjustable packing pieces could be fitted at each of the three points of support, so that the weight need not be left on the screws

after an adjustment had been made. A further simplification would be to use one screw at each of the three points of support, the nut being operated by a worm-wheel and worm. Mr. Gilbert.

Mr. R. A. Ryves thought there was one advantage of having seven piles instead of three, viz., that the seven piles, arranged as shown in the diagram, allowed of the roller-path being adjusted so that all the rollers bore equally. That made a good deal of difference in the amount of power which was required to turn the bridge. With three heads it would be more difficult to use the screw-arrangement shown on the diagram, because there would be much greater weight on each head, which might be a considerable hindrance to satisfactory working. For that reason alone, he thought the seven heads were better than three. Again, it was an advantage, especially in land which was sinking unevenly, as he understood the land did sink at Northwich, to have the larger number of supports. Three-legged stools were not easily turned over, but if the ground started sinking unevenly three-legged stools were in a much worse position than seven-legged stools. A complete ring instead of the seven piles had already been suggested. With regard to wind-pressure, one speaker had suggested making the short end of the girder solid, with no open work, so that when the wind was blowing the force on one side would be balanced by the force on the other; but if there were buildings which prevented the wind from blowing on both sides of the pivot at once, that arrangement would be of very little use. He supposed it would be hardly practicable to use a sail in any way, but he thought that a windmill might reasonably be used, because just when the motor had to deal with an extra heavy load in a gale of wind the power would certainly be supplied by the windmill. Whenever the power was required it would be there, and he thought a windmill would be a very simple arrangement to adopt, because the high speed of an ordinary modern windmill would be very easily applied to the sort of gearing used with the motor. Bridges of the kind described, if there were more built, would probably be provided with cross-bracing, so as to allow for the possibility of the weight being taken by the two ends. Mr. Ryves.

Mr. R. J. G. Read said the Author and several of the speakers had referred to the uneven sinking of the ground, which seemed to be a very important factor in connection with the design of the bridge. He would like to ask the Author if he could state what the sinking was due to. He understood it was caused by the salt being pumped out from underneath. If this was at a great depth he would not think that the ground could possibly settle unevenly Mr. Read.

Mr. Read. in the small area occupied by the piles. Remarks had been made with regard to the number of piles and the reduction of that number to three, Mr. Cruttwell going so far as to suggest a one-legged stool. He thought Mr. Cruttwell took a wrong view of the matter. His proposition would make the stool a box-seat. The one-legged stool would be represented by putting a single pile in the middle of the caisson and letting the caisson revolve round it. He did not know how that would work; it was merely suggested by what Mr. Cruttwell and others had said.

The Author. The AUTHOR, in reply, said he might first take the question of the number of the piles. It was thought at one time that three piles would be sufficient, but, of course, they would have had to be of greater area and strength. Putting it tersely, the chief object of not adopting so few piles was in order not to put all the eggs into one basket. With subsidence going on, it was thought adjustment would be much easier. One pile might go a little farther than the others, and there would be a better chance of adjustment than if the bridge depended on only three piles. With regard to the floating out of the pontoons for repairs, it would be noticed that there were only seven piles, and that the eighth pile was missing. That enabled the pontoons to be floated out one at a time. There would, of course, be a difficulty in floating out the back pontoon, and the whole thing would have to be turned round before that could be done, but he thought in such a case the bridge would have to be either turned off or left across the river while the repairs were being done, and it would not be exactly workable in such an extreme case as that. Provision had been made, however, for repairs. The bracing in the main girder was formed, in most cases, so as to act either as ties or struts, the contingency of the bridge being left across the river without a centre-piece being taken into consideration at the time. Before being accepted the navigation bridge was tested by means of two steam road-rollers, weighing 13 tons each, which were run side by side from one end to the other without appreciably deflecting any part of the bridge. With regard to the wedges taking the weight, there was only the 48 tons to be dealt with; the remainder was on the river, and the wedges were only driven home sufficiently to prevent the bridge from oscillating when traffic went over it. No difficulty had been experienced up to the present, and the bridge was always very steady when across the river, with the wedges home. It had already occurred that one side of the girder was found to be a little lower than the other, and the only thing necessary was to take

The Author.

the screw off its bearing and screw it a little bit farther into the nut, so that one wedge went home sooner than the other. That met the case exactly. As to the power of the motor, it was desirable that it should not be too small, and in comparing it with the power of engines put down for other bridges, and bearing in mind the fact that the bridge might have to be turned in a gale of wind, he thought he was, at any rate, keeping on the right side. He was rather astonished at the very low power required to move the bridge, and the very small cost. To follow up the point of power, he would like to say that he had already taken a number of diagrams with the recording ammeter, taking the direction and the velocity of the wind at the same time, with a view to get, if possible, some data to work upon in future. With regard to ball-bearings, although he was afraid they appeared from the diagram to be circular, they were in reality in a semi-V groove; in other words, the balls only bore at four points; they had not given the least trouble, and he would like to say that for the last fifteen years, if not more, ball thrust-bearings had been in use on the steam-tugs on the river, and some of those bearings had worked for years without the least attention. After a certain time the steel plates wore down and perhaps some of the balls split; but some of the tugs had been working for five or six years without the least attention to the ball thrust-bearings. He quite appreciated Mr. Ryves' point with regard to the adjustability of the seven piles to the rollers. As a matter of fact they had been used already for adjusting, and had been found very convenient. With regard to subsidence in the salt-district, it varied considerably in different places. It would be difficult to prophesy the exact form which it would take in any particular case, but for many years the site of the two bridges had subsided gradually in comparison with the other portions of the district, and although one side might go down a little faster than the other, there had been no tremendous pitfalls, where the ground had fallen to a depth of perhaps 20 feet at a time, as it did in some of the cases in the neighbourhood, and so far as one could tell there would not be any. The subsidence was caused in two ways; first, by the mining in the old days when the pillars were not left of sufficient size, and the mines filling with fresh water, the pillars gradually melted and let the top in suddenly; and, secondly, by the gradual extraction of the salt in the form of brine, by means of pumps. The pontoons were not lined with anything, but were very carefully painted inside and out.

Correspondence.

Mr. Clarke. Mr. THOMAS C. CLARKE remarked that in America an unyielding foundation was considered to be essential to the success of a movable bridge, but the Author seemed to have overcome the difficulties attendant upon a yielding foundation. There was some misapprehension as to the power required to move a well-constructed swing-bridge. The Third Avenue bridge in New York, of which he was the engineer, and which had now been in use about 18 months, was 305 feet long and 85 feet wide, and weighed 2,300 tons. It was carried on eighty cast-steel rollers having 10-inch tread, so that the pressure was under 6,000 lbs. per lineal inch of tread. It was operated by two 7-inch by 10-inch cylinder oscillating engines coupled to differential gear in the ratio of 19 to 1. The bridge was swung 90° in 1½ minute with 20 lbs. of steam in calm weather, running up to between 50 lbs. and 60 lbs. in heavy winds. This bridge was said to be the heaviest drawbridge yet constructed.

Prof. Gaudard. Professor JULES GAUDARD, of Lausanne, stated that bridges in general, but particularly movable bridges subjected to constant mechanical operations requiring considerable precision, needed very stable foundations. Now the most characteristic feature of the swing-bridges over the Weaver was the satisfactory solution they afforded in the very difficult case of ground exposed to considerable settlement. The Author stated the special conditions, and merely said that the existing forms of movable bridges were inapplicable; but it would be somewhat interesting to extend the discussion on this point, on which the chief novelty of the work under consideration mainly depended. The two fundamental arrangements which the Author had adopted were primarily a buoy or floating pontoon; and secondly a set of adjusting screws on the top of the cast-iron screw-piles which carried either the annular roller-path of the bridge or the extremities of the girders. As the Northwich bridges were three times as heavy, and had spans twice as great as the floating swing-bridges erected by Mr. Price in 1873, across passages leading to the Spencer Dock at Dublin:[1] the buoy was also larger. The buoy in this case was made of iron, instead of wood, and was formed of four distinct quad-

[1] Minutes of Proceedings Inst. C.E., vol. lvii. p. 17.

rants, probably with the object of facilitating its being put in place, or to reduce the loss of buoyancy in the event of a leak, like the watertight compartments of ships, or for some other unexplained reason. The flat sides of these quadrants constituted a network of diametric cross stays in the body of the caisson; but these stays could have been made single, and consequently with less metal, if the cylindrical outside case had enclosed a single compartment. Moreover, at the Dublin floating swing-bridges, the very small part of the weight of the roadway not borne by the buoyancy of the buoy was mainly carried by a central pivot under the bottom of the buoy, aided by a ring of horizontal guiding wheels rolling on the masonry lining of the well in which the buoy floated; whereas at the Northwich bridges the Author had thrown this surcharge on a row of cast-iron piles encircling the pontoon. This pontoon had three functions; it relieved the pressure on the foundations; it diminished considerably the load, and consequently the friction on the bearing-rollers, so that the swinging round of the bridge was rendered very easy; and lastly, owing again to the diminution of the load, it facilitated the raising of the bridge by means of the regulating screws on the top of the piles, on the occurrence of any notable settlement. With regard to the first point, it might be remarked that this sort of expedient might be applicable to other structures besides movable bridges. Thus the metal pier of a fixed bridge, formed of four screw-piles braced together, might well be provided with a caisson full of air closed both at top and bottom, the bottom being a little above the river-bed, and the top a little below the water-level at the low stage of the river; and in this manner the load on the piles would be lightened by the hydraulic under-pressure which this immersed float would exert. Nevertheless, it was quite intelligible why the builders of bridges had not had recourse to his method of lightening the loads on foundations; for, in the first place, infiltrations of water might eventually occur, weighing down the caisson, and in the end throwing the pressure on the ground which was intended to be relieved from it. In the second place, the benefit gained would not generally be sufficiently important. In fact, after all, the ground, however bad it might be, must be able to bear something. Assuming that the load imposed on the silty sand, in contact with the flanges of the screws at the bottom of the piles, was limited to the very small amount of 1 kilogram per square centimetre, or $18\frac{1}{4}$ cwts. per square foot, it would be expedient to alter the system of foundation; the float might be Prof. Gaudard.

Prof. Gaudard. got rid of on the condition of massing fresh piles in the large space which it occupied, or, still better, relieving the piles of their screws, and fastening their feet in a framework resting on a continuous foundation-platform of concrete or timberwork. With a pressure of 18½ cwts. per square foot, each square metre of this platform would sustain a load of 10 tons; whereas a pontoon filled with air would require to attain a submerged depth of 33 feet to obtain an equivalent lifting force, which was not generally met with. The conclusion might, therefore, be arrived at that, regarded as an expedient for a foundation on soft strata, a pontoon was of very moderate value, and that almost always a platform or apron having a large bearing-surface should be preferred to it. With a base widened out all round, a massive masonry pier might be built to a height of 25 feet, which would only put a load on the ground of between 1 ton and 2 tons on the square foot. Still more might such a structure be erected on the saline strata of Northwich, which, according to the statement in the Paper (p. 77), could sustain a load not exceeding 4·6 tons per square foot; but in the event of a considerable general settlement of the river-bed taking place, the Author seemed to have considered that it would be more convenient to put lengthening-pieces on the tops of several cast-iron piles than to raise a masonry pier by laying an additional course on the top. With regard to the second use of the buoy, namely, the reduction of the load on the turning-rollers of the bridge, it entered into competition with high-pressure hydraulic pivots, which had come into common use for swing-bridges. The Author's pontoon, with a mean height of about 14 feet, exerted a lifting pressure of only two-fifths of an atmosphere; whereas a hydraulic press, with a working-pressure of 50 atmospheres, required a horizontal surface of only $\frac{1}{125}$ the size, and would therefore be much less cumbrous. The press undoubtedly transmitted all its load to the ground, whilst the buoy floated in the river; but it had just been demonstrated that the foundation could safely dispense with this lessening of the load. Lastly, an objection might be raised against the use of water at high pressure, quite irrespective of the regular annual expenses involved, that the pressure-supply pipes might be injured by the settlement of a yielding soil; but even this objection did not appear to be insuperable, since the Brandt hydraulic rock-drills, and the hydraulic riveters on bridge-works had led to the construction of jointed pipes which were both flexible and water-tight, and at the same time able to stand very high pressures. The third use of the pontoon was undoubtedly the most im-

portant, for it limited to 48 tons the resistance to be overcome in raising, by means of the regulating screws, the whole weight of the bridge of 303 tons, in the event of a settlement of the ground. Nevertheless, was it really proved that an advantageous method of raising this bridge by means of a hydraulic pivot could not be found? It would appear to suffice to construct the press with an excess of optional lift; and then it would be always possible, when desired, to raise the bridge, balanced on its central pivot, to a sufficient height by hydraulic power to relieve the turning-rollers and the bearing wedge-blocks entirely from pressure, which would afford every facility for raising the supports of the latter and the roller-path of the former, whether this raising was accomplished by regulating screws as in the case under consideration, or simply by screw-jacks and the insertion of heightening-packings. The cylinder of the central press might then be similarly raised, after propping up the girders of the bridge alongside it with temporary wooden supports, enabling the water to be let out of the press. The piston, indeed, might itself serve to raise its cylinder, if it was so arranged as to be able, if required, to receive the water on its annular superior face around its rod, and if this piston-rod terminated in a projecting head, rendering it possible to suspend it from the platform of the bridge. It might now be considered whether other systems of movable bridges, besides the swing-bridge revolving on a vertical axis, could not have been rendered equally applicable to the conditions of Northwich, by having recourse to certain ingenious contrivances similar to those which the Author had devised. Rolling or traversing bridges would have to be excluded from the competition; for the bridges over the lock of the St. Malo dock and over the Penhoët lock at St. Nazaire, showed that a bridge with traversing and tail ends not only comprised three points of support, which had to be maintained on a level, but also that it was necessary to arrange at the back a whole series of bearing-rollers for the tail end to be rolled back over, which were obliged to be kept in absolutely exact and fixed positions; and therefore this system of movable bridge was specially unsuited to bear settlement. Bascule bridges turning on a horizontal axis possessed the special inconvenience of requiring an underground chamber in the form of a quadrant, for receiving the tail end when the bridge was raised; or, in the case of a simple drawbridge, to be counterpoised by a weight suspended from a chain passing over a pulley on the top of a pedestal. The axis of rotation, being placed on the abutment, would undergo the settlements to which this latter might be subjected. It would Prof. Gaudard.

Prof. Gaudard. therefore be necessary, on unstable ground, to be provided with a means for raising the sockets of this axis, on which the whole load of the bridge fell, to their original level. The rising, or lift type of bridge, with a vertical movement, offered the great advantage of dispensing with all rigid connection between the movable platform and the abutments, so that the settlement of the abutments would not alter in any way the bending stresses on the girders, since these had only two points of support; and, moreover, if the settlement became too great, it would be only necessary, whilst the bridge was raised, to add packings or extra thicknesses to the bearing-plates in order to restore the bridge to the level at which it was originally placed. This kind of movable bridge was the least in the way of any, since it was lifted into the air, and it was very approximately balanced by counterpoise-weights, whose cables passed over large pulleys on the top of guiding pillars, so that the lifting of the bridge was rendered easy. As a surcharge load transmitted to the ground, these balance-weights were only the equivalent of the weighted tail end of swing-bridges, and, moreover, these latter, during their swinging, concentrated their load on a single pier, whereas the lift-bridge always distributed its load equally between the two abutments. A steam-motor could, indeed, be placed on the movable platform and accompany it in its ascent, as effected by the New York and Buffalo Railway at the crossing of the Oswego Canal at Syracuse; but even when leaving this engine on the ground, there was no line of pipes to be interposed between it and the moving bridge, nor any special motive for having recourse to electrical transmission. The lifting, in fact, being accomplished by the intervention of cables, their rolling up or unrolling would simply have to be carried more or less far to shift the moving roadway between any two different altitudes, notwithstanding the settlements which might have modified the initial relative positions of the pillars and the bearing-plates of the girders of the bridge. In respect of the height of lift, every requirement could be satisfied, since Mr. Waddell had constructed a lift-bridge at Halsted Street, Chicago, which could be raised 140 feet, whereas at Northwich the maximum headway required did not exceed 55 feet. Moreover, those bridges were only lifted in each case to the height required for the particular boat to pass under them, and the time needed for the operation was very small, since the bridge at Chicago could be raised 100 feet above the water in only 50 seconds. The pillars might, indeed, settle down out of their vertical position in unstable ground, which would be a fairly serious inconvenience with this system of bridge; but

again the rectification of this deflection had been provided for by putting a large regulating-screw under some of the uprights of these pillars, and this screw had a spherical end embedded in a cast-iron socket, which left it free to turn under the action of the working-key. As regarded the vertical settlement of the pillars, provision would be made for such a foreseen contingency in a project to be carried out on unreliable ground by giving them an excess of height, so that the upper pulley might, under every condition, preserve a sufficient altitude for the requisite raising of the bridge to afford the full headway. If the four pillars happened to settle irregularly, an adjustment of the working-length of the corresponding cables would restore the parallelism of travel of the four corners of the platform. Nevertheless, he supposed that it must have been this doubt about the stability of the pillars which led away the Author from the study of a lift-bridge. If the Author had also been influenced by other unfavourable considerations, it would be interesting if he could kindly state them. As pointed out by the Author, the tail end of the Northwich bridges was relatively short; it was, in fact, only $\frac{1}{2 \cdot 2}$ of the swing portion, instead of the ordinary proportion of between one-half and three-fifths. Nevertheless, the swing-bridge of the naval arsenal at Tarente might be cited, where the ratio was as low as one-third. Prof. Gaudard.

Mr. JAMES PRICE observed that the principle described in the Paper, of carrying part of the moving weight of swing-bridges on floats, was the same as that introduced by the late Mr. James Price, M. Inst. C.E., about 30 years ago, and described by him in a Paper read before the Institution in 1879.[1] In this Paper the use of floats was specially recommended where there was a difficulty in getting a solid foundation. In the Weaver bridges 84 per cent. of the load was taken by the pontoons, while in the Spencer Dock bridges referred to 95 per cent. of the load was so carried. He considered that the use of floats was the best method of constructing a swing-bridge where the foundation was bad, and even where the foundation was good this method might be applied with advantage to relieve the heavy loads on the ordinary rollers of swing-bridges. He had had experience of the bad effects of such loads in a swing-bridge under his charge; the roller-path was much worn, though the bridge in question has only been in use 15 years; and the renewal of the roller-path without interruption of street-traffic or navigation seemed almost impossible except at the expense of a temporary bridge. There was also a Mr. Price.

[1] Minutes of Proceedings Inst. C.E., vol. lvii. p. 1.

Mr. Price. difficulty in keeping the roller-paths free from dust-deposit; the shields described in the Paper might partially prevent this, but they were likely to add to the difficulty of cleaning should such deposit take place. The necessity for a very clean and even roller-path might be obviated by the use of wheels (say 3 feet in diameter), with the load carried on fixed axles working in roller-bearings, instead of the ordinary rollers generally in use, which, being of small diameter, were obstructed by any unevenness in the roller-path. He considered that the sites of the Weaver bridges necessitated the great difference in the lengths of the moving parts at each side of the turning centre and a consequent heavy kentledge (apparently about 100 tons); but that the weight of kentledge might have been reduced to about 20 tons by placing the centre of the floats considerably nearer to the centre of the moving part of the bridge, the part of the tow-path under the bridge being carried on the floats so as to get the extra room then required. A long column turning centre (such as was used in American bridges) might have been substituted for the roller-path arrangement, the entire weight of the moving part of the bridge, which would then be about 220 tons, being taken by the floats. He would like to know if any arrangement was made for scaling and painting the outside of the iron pontoons, and whether the sectors were removable, so that one could be taken out for painting, while a duplicate sector was put in to keep the bridge working without putting any extra load on the rollers.

Mr. Robinson. Mr. John Robinson remarked that the method adopted by the Author was both ingenious and novel, and appeared to be equally efficient with counterbalanced bridges operated by either steam or hydraulic power. He thought that electrically-operated swing-bridges would, in the future, be introduced where the circumstances were favourable; for instance, in swing-bridges for dock-traffic, where electrically-driven cranes and capstans were used: and the application of electric power might be further extended to coal-shipping appliances, and to the opening and closing of dock-gates and sluices. Although it might not be more efficient or more economical than hydraulic power for coal-hoists or coal-tips, yet it might be found advantageous in the working of the dock-traffic to have only one installation, and that electrical, instead of having both electrical and hydraulic installations. Electric power was free from the danger to which hydraulic machinery was exposed in severe frosty weather; and electric conductors were said to be less liable to injury than any other means of power-distribution. For the purpose of comparing, in some measure, the relative

efficiency of electric and hydraulic power in operating swing-bridges, he had taken the double-ended swing-bridge at Middlesbrough as an illustration of a bridge worked by hydraulic power. The bridge over the River Weaver, having a bowstring lattice girder 122 feet long, carrying a roadway 19 feet 6 inches, and two outside footways, each 4 feet 6 inches wide, was turned through an angle of 80° in 45 seconds; whilst the double-ended swing-bridge at Middlesbrough, spanning two locks and having plate girders 169 feet long, with a width of 16 feet between them, carrying a line of railway and footpath, was turned through an angle of 81° in 37 seconds, in the ordinary working of the lock-traffic. The double-ended swing-bridge referred to had nearly equal arms—86½ feet and 82½ feet—and, being better balanced, was more easily turned, especially in windy weather, than a swing-bridge counterbalanced with kentledge, like those over the River Weaver, which had unequal arms of 38 feet and 84 feet respectively. A steady wind had little or no effect on the swinging of the bridge at Middlesbrough, as the pressure on one side of the centre was nearly balanced by that on the other. Any further information the Author could give as to the resistances, due to rolling and sliding friction, inertia, and wind, and particularly to rotary motion in water, of these novel swing-bridges resting upon pontoons and rollers, when being turned, would be very interesting. He would be glad to know from what depth below the surface brine was pumped in the neighbourhood of the bridge described, because saturated brine was being raised through tubes inserted in bore-holes from a considerable area of rock-salt in the Middlesbrough district, more than 1,000 feet below the surface on which were built many industrial works; and the question had arisen what danger there might be to the land and works from any subsidence of the ground, notwithstanding that the place of the abstracted salt was taken by water and that there might be no voids. He thought adjustments for keeping the roller-paths true might be of fairly frequent occurrence under the circumstances related, and it was wise to provide suitable contrivances for the purpose. With regard to the slow progress made in screwing the cast-iron piles into the ground, it would have been better, he thought, if the serrated edges had been dispensed with. That was his experience, and he had used in various kinds of soil hollow cast-iron piles, having diameters varying between 15 inches and 30 inches, and blades up to 6 feet, both with plain cutting and serrated edges, and he found that the latter hindered rather than helped in screwing the piles down. A serrated edge Mr. Robinson.

Mr. Robinson. to a pile without blades and heavily weighted with kentledge might be of use when screwing in certain kinds of friable material; but screw-piles with blades for soft ground went down best with plain cutting edges. He would be glad if the Author would describe the kind of dredger-grab used in excavating the fine wet sand from the pontoon-chamber, because he had a quantity of sandy silt to remove from the interior of some concrete monoliths not yet sealed, and the grabs at present employed were of scarcely any use.

Mr. Thorpe. Mr. W. H. THORPE remarked that a less costly bridge might perhaps have been constructed by supporting say 85 per cent. of the weight upon the caisson, 10 per cent. upon a central pivot, and 5 per cent. upon wheels at the short ends of the girders, running upon a tail-race. In this way the greater part of the load would float, as in the Author's design, the remainder being carried at the three points of a triangle. Settlement would not distort the superstructure of the bridge, and the adjustments necessary to bring all to a level again would be simpler. The turning-gear would be situated at the tail end, blocking-up being effected there also, first causing the nose end to rest upon plain bearings, and finally lifting the 10 per cent. of the weight free of the pivot. The whole of the gear-appliances would thus be situated at one end of the bridge, and there would be a constant reaction due to flotation of the caisson, with all stresses definite; the girder detail immediately over the caisson would be simpler, and access to it, or its removal if necessary, would be facilitated. The swinging of such a bridge with a wind blowing across its length would induce some rather curious stresses due to torsion of the structure; there appeared to be nothing in this, however, that could not be properly provided for. In any case, it was extremely improbable that a bridge over a river would ever be required in practice to open under a wind-pressure of more than 10 lbs. to the square foot.

Mr. Wells. Mr. LIONEL B. WELLS remarked that the old two-arched stone bridge spanning the Weaver at Northwich was built in 1663 and remained till 1858. The new bridge provided a headway of 15 feet 10 inches. The peculiarities of the salt-district and the subsidence which took place had been described[1] by Sir E. Leader Williams. The bridge commenced to subside prior to 1875 and by 1884 had gone down more than 3 feet, which must be added to the 6 feet mentioned by the Author, so that the total subsidence had been 9 feet. In 1879 Mr. Wells had reported on the bridge. The headway available was only 14 feet 6 inches, and craft were then plying

[1] Minutes of Proceedings Inst. C.E., vol. lxx. p. 378, and vol. xc. p. 149.

Mr. Wells. on the navigation which required a headway of 14 feet 6 inches at their light draught. To avoid raising the approaches he had reconstructed the flooring and cross girders, and was thus enabled to provide a headway of 16 feet 2 inches. This was done in 1881, at which date the available headway had been reduced to 14 feet 1 inch by continued subsidence. During this period the navigable depth of the river was being increased and more headway was required to accommodate the larger vessels. The only real solution of the difficulty was to provide an opening bridge, but the opposition raised by the townspeople was so strong that the Weaver Trustees abandoned the proposal and ordered the west end of the bridge to be raised, thus gaining 1 foot 6 inches additional headway. Eventually the Trustees were compelled to apply to Parliament, as the navigation was seriously hampered by the conditions which prevailed, especially as an important trade was done from Winsford, which was 6 miles higher up the river. The Act empowered a swing-bridge to be substituted for the fixed bridge, but, unfortunately for the navigation, required two bridges to be built and maintained. The River Dane (*Fig. 16*) joined the Weaver at right angles to the line of the navigation and was subject to high floods, so that this was at times a very difficult length to navigate, especially with trains of barges; and when not in flood trains of four barges, occupying a length of between 600 feet and 700 feet, would find it difficult to pass in the interval between the bridges, which were only 800 feet apart. Besides being objectionable to the navigation, the cost had been more than doubled, owing to the expense of making new streets having been borne by the navigation. He thought the only reasonable ground for insisting on two bridges was that people wishing to use the town bridge and finding it open could go round by the other bridge. It would be interesting to know how many persons followed this course in a specified time, say a week or month. He imagined very few would do so, for while making the detour the town bridge would become available. Perhaps the Author could supply information on this point. Parliament and local authorities were much too ready to burden with expenditure all new enterprises—a wasteful and extravagant policy, tending to keep up the cost of transport; and this was a very important question, for whereas the ordinary cost of land carriage in Europe half a century ago was 8*d.* per ton per mile, it had been reduced to less than 1*d.*, and English rates, instead of being the lowest, were now the highest. This, as competition became keener year by year, would be more acutely felt by the community. Traders had lately been seen clamouring for a re-

Mr. Wells. duction of railway- and canal-rates, and with some effect: it would be well if they also assisted in the curtailment of expenditure. He had examined the Navigation Bridge soon after its opening, and the work appeared to have been executed in a very satisfactory manner in its various details. The palisading to the footpath, as was apparent from the drawing, was heavy and out of proportion to the width of footway. He understood it was in accordance with the requirements of the highway authorities. In 1872 the Weaver Navigation inaugurated the canal-lift system at Anderton. He was glad to see that they were still in the forefront by their adoption of electricity for operating swing-bridges. The Weaver water contains a considerable quantity of salt in solution. It would be interesting to know how the pontoon, presumably of steel, had been protected from oxidation, and what was the process to be adopted when it required renewal or extensive repair.

The Author. The AUTHOR, in reply to the Correspondence, said he was much interested to hear of the magnitude of the Third Avenue Bridge at New York; Mr. Clarke had, however, not given sufficient data to ascertain the power required under the different circumstances. Professor Gaudard's dissertation reminded him of the train of thought which had passed through his own mind previous to his decision to adopt the form of bridge now erected, and he was pleased to find that Professor Gaudard appeared to have arrived at the same conclusion as himself, viz., that the form adopted presented fewer maintenance-difficulties than any other form. He had already mentioned the reason for having the pontoon in four parts, viz., to facilitate removal and lessen the danger of complete disablement. With regard to the suggested masonry base, Professor Gaudard appeared to have overlooked the fact that 4·6 tons per square foot was the maximum temporary load on the ground in case of entire failure of the pontoon, and that the normal load was only a fraction of that weight, viz., $\frac{48}{303} \times 4 \cdot 6 = 0 \cdot 72$ ton, or 14·4 cwt. per square foot. The cause of the subsidence was at least 150 feet down, and actual strata at the surface, although consisting of sand and sand mixed with clay and gravel, subsided from the withdrawal of the support below, and not from any inherent defect in its own nature. The reasons for not adopting hydraulic power of high pressure for turning the bridges were not only the placing of the weight on the ground instead of the river, but also the great cost and difficulty of maintenance of a pumping-station, which with its accumulator must

have been on subsiding land. The flexible pipes mentioned had not been overlooked by him, but he considered that although in constant use they were very serviceable, yet should joints in such pipes be buried in the ground, as in this case they would have been, they would in all probability become stiff and not act when the time for action arrived. His objection to a lifting-bridge, which he also had under consideration, was chiefly that suggested by Professor Gaudard, viz., that if the four pillars settled irregularly and departed from the vertical, the columns, over 55 feet high, would have been subjected to considerable bending stresses of an uncertain nature. He had had an opportunity of seeing the Spencer Dock Bridge, Dublin, while the Northwich Bridge Bill was in Parliament, but ventured to think, with all due deference to the late Mr. James Price, who had courteously explained it to him, that the works were not comparable, except in the fact that they were both partly water-borne. The towing-path could not be carried over the pontoons as suggested, as examination of the drawings would show that such an arrangement would foul the connecting girders between the pontoon and the bridge. In reply to Mr. John Robinson, he had already found the advantage of electrical power for cranes, and had utilized existing boiler-power to operate hoists some considerable distance away. Unfortunately Mr. Robinson did not give the horse-power required to turn the Middlesbrough Bridge, so that it was impossible to make a comparison. He could not give any further data at present beyond the ammeter-diagram given in the Discussion. The bucket used in the dredger was a plain-mouthed grab-bucket of the Priestman type. In reply to Mr. Thorpe, the Author thought there would be an insuperable difficulty in the way of ensuring the proportions of 10 per cent. and 5 per cent. on a pivot and rollers, as an uneven settlement might throw the whole weight on either; also, the pivot would have to pass up the centre of the pontoons, and would therefore be inaccessible for adjustment, and in the way if thrown out of perpendicular. In furtherance of Mr. Wells' remarks, as to the rate of subsidence, he had found in November, 1887—when he took charge of the river—that a mark on the worst corner of the old bridge stood at 49·54 above Ordnance datum, and this became, by more or less rapid subsidence, 47·70 in January, 1893; he had then raised it to 48·79, but by the 14th November, 1898, when the demolition was commenced, it had sunk to 47·78, or 2·85 feet in 11 years. All the surrounding property had also subsided, so that further raising would have been intolerable. The adjacent The Author.

The Author. bridge over the River Dane had subsided from 49·45 to 43·20, or 6·25 feet between 1882 and May, 1897. The expense of removing the obstruction was, no doubt, largely increased by the erection of the second bridge with roads, &c., but it must be remembered that the risks of small failures to any form of movable bridge on this site were greater than they would be on firm ground, and also that the cost of a temporary bridge—which must have been practically on the site of the Navigation Bridge—had been saved. The difficulty of navigation at this point had much decreased since the period Mr. Wells referred to, owing to the increase in the size of the "Flash" shown in *Fig. 16*, which created a slack water, and enabled vessels to draw up to await the opening of the Town Bridge, should it not be ready. He had no data as to the number of persons making the detour, and doubted if any foot-passengers attempted to do so, unless, as in some cases, their route was scarcely altered. It frequently happened, however, that vehicles from Winnington, hurrying for a train at Northwich, used the second bridge, as the difference in time did not exceed three minutes. He had already replied as to the renovating of the pontoons; they were painted with three coats of red-lead paint and two of a mixture of tar, red lead and cement, applied hot, before being launched. The salt in the Weaver did not exceed about 0·3 per cent. in the summer, and 0·15 per cent. in the winter, and he had found that submerged iron and steel work did not suffer more than in other inland waters, a vegetable film forming on all submerged work, which appeared to protect it.

30 January, 1900.

SIR DOUGLAS FOX, President,
in the Chair.

(*Paper No. 3191.*)

"Steamers for Winter Navigation and Ice-breaking."

By ROBERT RUNEBERG, Assoc. M. Inst. C.E.

THE development in the winter navigation of northern waters, which, in a Paper[1] communicated to the Institution in 1889, the Author ventured to predict, has been realized. Many harbours formerly closed for several months in the year are now kept open by means of ice-breakers, and navigation is frequently rendered possible the whole year round. But a very important factor in successfully navigating freezing waters is the adaptation of trading steamers to the peculiar conditions under which they work. One of these special features of winter navigation was thus described in the Paper referred to:—

"When the temperature is very low, there is generally comparative calmness in the atmosphere; but such is not always the case. A temperature many degrees below zero may sometimes be associated with great atmospheric disturbances, and in such case waves breaking over a ship will not entirely run back into the sea, but will leave a layer of ice behind them. The spray and foam glaze the boats and rigging, and a solid mass is gradually formed wherever the water is more or less retained by coamings, hatchways, bulwarks, or other projections. The position may even become critical if the design and general arrangements of the vessel are unfavourable for riding out a storm of this description. The crew vainly attempt to cut away the shroud of ice and clear the decks; each returning wave will add to its thickness, and, as the vessel sinks gradually lower and lower in the water under its load, the less, of course, grows its chance of escape."

[1] Minutes of Proceedings Inst. C.E., vol. xcvii. p. 277.

Winter navigation in the northern seas is extremely hazardous with ships that are not suitably designed and properly equipped, but experience has shown that steamers constructed for the special service have very little to fear from the ice, and that winter navigation with such ships has become comparatively safe. In Finland remarkable results have been gained in introducing trade steamers suitable for winter traffic. There is scarcely any other civilized country subject to more pressing necessity of finding means to overcome a hard climate. Before the year 1877 Finland was closed to navigation for 5 months in the year. Now communication is kept up, practically speaking, the year round, with regular trade steamers between Hangö and England, Germany, Sweden, and other countries.

As illustrations of steamers now used for winter navigation may be mentioned "Aegir," Figs. 1, Plate 4. This boat belongs to the Helsingfors Steamship Company, and was built in 1896 by the Nylands Works at Christiania. She trades during the summer between Helsingfors and Lübeck, and in winter between Hangö and Lübeck. Her dimensions are:—

Length over all	182 feet.
Length between perpendiculars	172 feet.
Breadth	28 feet.
Depth moulded	14 feet 6 inches.
Dead weight at 16 feet draught	500 tons.

She is classed in Veritas + 1.3/3 C 1.1. P.R. The engines are of compound type, developing about 500 HP. The shafts are made 25 per cent. stronger than is prescribed in Veritas rules. The form of the hull resembles that of the modern ice-breaker, the only modifications introduced being necessitated by her cargo-carrying requirements. The "Aegir" has a flush upper deck, and is double bottomed all along. The midship section shows, compared with Veritas requirements, considerably increased scantlings in the way of the water-line. The strength of stem, stern-post and rudder are also augmented. Notwithstanding the small size of this boat she has done excellently, and may well serve as a type for this class of vessels.

Before giving particulars of the modern types of steamers used exclusively for ice-breaking, it may be of interest to consider the principal modifications that have been effected in the design and construction of this class of vessel during the last few years.

For several years the lines of the "Eisbrecher I.," built for the

Elbe at Hamburg in 1871, have been more or less generally followed, and it was thought that the bow ought to have the spoon form which this vessel presents. The fore part of several ice-breakers is shown in Figs. 2–13, Plate 4, arranged to illustrate the gradual change that this spoon form has undergone.

It is well known that a steamer built according to the European type breaks the ice on the principle that the sloping bow rises until its weight overcomes the resistance of the ice, which then breaks; the bow descends, and the steamer progresses again to elevate the fore-end on the ice-edge. The elevation varies according to the form of the bow and the stern and the power of the engines, but for most ice-breakers it amounts to only a few inches as long as the boat is progressing steadily and is not making a charge. When the ice is too thick to allow steady progress, the boat retires a few hundred feet and charges against the ice at full speed. In this case the elevation is measured in feet, now depending chiefly on the *vis viva* of the boat. But in both cases serious inconvenience is incurred by the spoon form of the bow. The ice is generally covered with more or less snow, or the water may be covered with snow and lumps of ice mixed. This is pressed forward by the fore end of the vessel, and is heaped up against the bow, causing a considerable resistance. Further, the rounded bow makes it extremely difficult for the steamer to deviate to one side of a previously broken path in the ice.

The Author has on several occasions advocated a more protruding stem, greater inclination of buttock lines and S-formed water-lines in the fore end, both for the above-mentioned reasons and also on theoretical grounds, which point to greater efficiency of ice-breaking in general. Seemingly by mere chance, the correctness of this view was confirmed in practice in 1891 in the s.s. "Svensksund," Figs. 8, Plate 4. She was a gunboat, but proved herself to be a better ice-breaker than any other of her size. Shortly after, designers of ice-breakers became more inclined to adopt a pointed bow with S-formed water-lines; for example (see Plate 4), s.s. "Tyr," 1893; "Isbjörn," 1894; the Gothenburg ice-breaker, 1895; and most obviously in the "Ledokol," built to the Author's design in 1895. The advantage of this modification is now fully established. In his former Paper, the Author gave the following formula for calculating the ice-breaking capacity of a steamer:—

$$t = c\sqrt{\frac{V}{\sqrt{B}}},$$

where t = thickness of ice in inches.

V = vertical pressure of the bow on the ice in lbs.

B = breadth of the ship in feet.

c = a constant.

V being found from—

$$V = \frac{12{,}375 \text{ I.HP. } (\cos\phi \cos\beta - f \sin\phi)}{N\,P\,(\sin\phi\cos\beta + f\cos\phi)}.$$

In this expression—

N = the number of revolutions per minute.

P = pitch of propeller in feet.

f = coefficient of friction, taken as 0·05.

β = angle between water-line and mean inclination of cross sections taken perpendicular to buttock-lines.

ϕ = angle between mean inclination of buttock-lines and water-line.

The constant c was taken at 0·18, based upon observations on actual performance of various ice-breakers. But the great influence of even a slight snow-cover on the ice, especially for the spoon-formed bow, was at that time overlooked; and only the net thickness of the ice was measured, leaving the snow out of consideration. On this account the ice-breaking capacity at several trials was greatly underrated, and the constant, instead of being 0·18, is probably at least 0·3 for snow-free ice.

But it should be observed that the ice itself is of considerably varying resistance, depending on the way it has been formed, its age, and on the temperature at the time of trial. It is well known that fresh water has its greatest density at 4° C. above zero, but in salt water the point of maximum density falls more or less below zero—indeed, even below the virtual freezing point of the salt water itself.

This property of salt water sometimes gives rise to an interesting kind of ice formation. If fresh water is kept quite still its temperature may be brought below the freezing point without the formation of ice. Contrary to this, the salt water may be kept in movement without ice appearing, although the temperature is below the freezing point. Now, when the temperature of the atmosphere is low, the surface water becomes cool and sinks, warmer water takes its place to lose heat, become denser and return below; thus a circulation is established which may cool a layer of water below the freezing point to a considerable depth. If now something occurs to disturb the equilibrium of the particles, ice will be spontaneously formed throughout the whole mass of

water cooled below the freezing point, and the temperature of the water will instantly return to the freezing point. The new-formed particles of ice rise to the surface and form a more or less thick layer without any solidity whatsoever. If the frost continues, this mass will gradually be cemented together, beginning from the surface; but before the process has reached through the whole thickness of this conglomeration, the resistance or strength of the ice evidently does not stand in proportion to its depth. It is difficult to judge whether ice built in this way ever attains the same strength as the surface ice formed in the usual way, viz., at first a very thin sheet, gradually thickening.

The temperature has also considerable influence on the resistance of the ice. Exhaustive experiments on the resistance of ice are still wanting. The tests that have been made show, nevertheless, very great variation of resistance, depending in the first place on the temperature, but also no doubt on the structure of the ice itself.

Frühling, of Königsberg, found the modulus of rupture of bars of ice at $-1°$ C. to $2°$ C. to vary between 11·1 kilograms and 28 kilograms per square centimetre, while at the temperature of $+1°$ to $+4°$, it ranged from 7·1 to 9·4 kilograms. The tensile strength was found to be 13·3 kilograms, and the resistance to crushing ranged from 15 kilograms to 27·26 kilograms.[1]

According to trials made in Philadelphia by W. Ludlow, pure and clean ice from the river Kennebec showed a resistance to crushing of 23 kilograms to 70·7 kilograms per square centimetre, depending on the temperature.[2]

Professor Kolster, of Helsingfors, has made a number of tests with ice brought direct from a temperature below $-20°$ C.[3] The results are comparatively high, the resistance to crushing varying between 28 kilograms and 68 kilograms per square centimetre, with the exception of one test, giving only 9 kilograms, for reasons which are not explained.

Seeing that all the experimental trials of the resistance of ice have shown such great variations, it is not to be expected that, with the present knowledge of this question, a formula for the breaking capability of a steamer could give any but approximate results, even where the snow-cover on the ice is removed.

But with the gradual increase of the power in modern ice-breakers, it has become evident that the evenly laid and uniform

[1] Zeitschrift des Vereines deutscher Ingenieure, 1885, p. 357.
[2] Proceedings of the Engineers' Club of Philadelphia, vol. iv., p. 93.
[3] Proceedings of the Finnish Tech. Soc., 1893, Nos. 1 and 2.

ice no longer presents any serious hindrance to winter navigation. The plain ice never seems to reach a greater thickness than 2 feet 6 inches, or perhaps 3 feet, excepting in the Arctic Ocean, where the ice formations are still very little known. Mr. Sverdrup, the captain of the "Fram," informs the Author that the thickness varies between 6 feet and 10 feet at places where there is no pack ice. The usual thickness in the Baltic, even in severe winters, seldom exceeds 18 inches to 24 inches. An ice-breaker of 2,500 I.HP., with the propeller aft but otherwise of modern design, should be able to work its way through this ice, if not covered with snow, without stopping, and if covered with snow she will still advance fairly by charging.

The great problem is how to clear the drift ice, or rather the pack ice, which in the Baltic reaches to a depth of several fathoms. Some years ago, accounts appeared of wondrous feats accomplished by American ice-breakers. They were described as easily working their way, with their fore propeller, right through pack-ice resting on the bottom of the sea. It was not unusual to see the propeller, though placed aft and thus better protected, often break its blades when coming in contact with the ice. How could a similar screw work successfully in the fore end?

It had often been observed that a steamer going astern sometimes made better progress than when going ahead. Mr. Frank E. Kirby accordingly constructed an ice-breaker with a propeller in the fore end also. The Straits of Mackinac were extremely difficult to pass in winter-time when ice drifted in from the great lakes, and it was necessary to have railway trains ferried across. Mr. Kirby undertook to design a ferry, to be built by the Detroit Dry Dock Company for the Michigan Central Railway Company, in which was embodied the new idea of having a propeller in the fore end to assist in breaking the ice. Thus the "St. Ignas" was completed in 1888, and proved a success. Her principal dimensions are:—

	Ft.	Ins.
Length over all	235	0
Breadth	51	6
Depth	25	0
Draught	15	8

The engines are compound, the aft engine developing 2,000 I.HP. at 90 revolutions per minute, the fore engines 1,000 I.HP. at 100 revolutions. The steam pressure is 120 lbs. per square inch. The diameter of the aft propeller is 12 feet, with $16\frac{1}{2}$ feet pitch, and of the fore propeller 10 feet, with 15 feet pitch, both being of cast steel. The hull is built of wood sheathed with $\frac{1}{4}$-inch steel plate to above the load-water line

The fore propeller was made extra strong, and it should be noted that no propeller blade of the "St. Ignas" has been broken. Once the fore propeller was entirely lost, but the reasons have not been made known.

The method by which this new craft worked in pack-ice was somewhat different from the European plan. When an ice-breaker of the old school was stopped by a pack-ice belt she backed astern a few ship's lengths and made a fresh charge, which always brought her a little way further in the ice. But the steamer described rests with the bow against the ice; throwing the fore engines back, the propeller sends a stream of water among the pack-ice, loosening the grip between the separate blocks, and, as soon as the engines again are reversed, lumps of ice are carried aft by the stream from the fore propeller. The aft engines are, during this operation, constantly working forwards, and, having greater power than the fore engines, keep the boat against the ice.

This ferry-boat having proved a success, the "St. Marie" was built in 1892–93, somewhat more powerful and longer, in order to take seventeen or eighteen wagons, whereas the "St. Ignas" only carried ten. Further, the ratio of the power of the fore and aft engines was changed, the fore engines being given the greater part of the increase, or, in all, 1,800 HP. at 100 revolutions per minute, while the aft engines develop 2,200 HP. at 90 revolutions. The compound system was again adopted. Figs. 14, Plate 1, show the lines of the "St. Marie," her principal dimensions being 304 feet × 50 feet 6 inches × 24 feet, and 17 feet draught. Since the railway company have employed these two ferry-boats, the regular traffic across the straits has only been interrupted for at most a few days at a time. Still it does happen that the boats stick in the ice. Generally the "St. Marie" is running and the "St. Ignas" is kept in reserve. When the first-named has stuck, and cannot get clear, then the "St. Ignas" is called out to assist, and, by their mutual aid, means are usually found for getting over the difficulty.

The Craig Shipbuilding Company of Toledo followed, and built, in 1892, two similar steam ferry-boats for the Frankfort-Kewaunee line, named "Ann Arbor I" and "Ann Arbor II." The principal dimensions of the "Ann Arbor I" are:—

	Ft.	Ins.
Length over all	267	0
Breadth	52	0
Depth	18	6
Draught, loaded	12	0
„ light	9	10

Fore engines, compound, 550 HP. at 95 revolutions per minute. Aft engines, twin-screw compound, 1,160 total HP. at 93 revolutions. Aft propeller, diameter 9 feet, and fore propeller 8 feet 3 inches.

The "Ann Arbor II" has a slightly larger hull, but the same engine-power and diameter of propellers.

The good results obtained with the American railway ferry-boats were soon appreciated in Europe. One of the most difficult and expensive parts of the Trans-Siberian Railway is along the great Baikal Lake, and so it was decided to follow the example of the Americans and to build a powerful steam ferry-boat to carry the trains across the lake, and to leave the construction of the railway line round the shore for a future operation.

The Russian Government ordered, consequently, a steam ferry-boat of the American type, to be built by Messrs. Armstrong, Whitworth & Co., of Newcastle, in the year 1895, and it is expected that she will be at work on the Baikal this year.

The principal dimensions are:—

	Ft.	Ins.
Length over all	290	0
Breadth on main deck	57	0
„ „ water-line	53	6
Depth	28	6
Draught, in fresh water, laden aft	20	0
„ „ „ „ „ forward	17	0

She is to carry twenty-five cars, weighing 500 tons, with fuel, stores, spare gear, passengers and luggage, 250 tons. The indicated HP. is to be not less than 3,750.

The main carriage deck has three lines of rails tapering into one at the fore end of the vessel. Double bottom extends from the forward engine-room bulkhead to the after-peak bulkhead, and the vessel is divided into eight main compartments. Twin screws aft will be driven by two independent engines of triple-expansion surface-condensing inverted type, and one similar engine at the forward end. The hull is built of mild steel and iron under the supervision of Bureau Veritas. For working amongst ice the ends of the vessel are strengthened by spacing the framing 18 inches apart, the remainder being at 24 inches distance; and, furthermore, an 11 feet wide wood backing is fitted in the way of the water-line. The stem and stern-post are of cast steel, and the rudder is of the balance description. The outside plating is of steel. The keel strake and two strakes at the water-line are 1 inch thick, the rest being $\frac{9}{16}$ inch to $\frac{7}{8}$ inch.

Two dynamos are provided, intended to feed 250 lamps and one 20-inch projector of 20,000 candle-power.

The three main engines are, as far as possible, alike, and each set is expected to develop 1,250 HP. The cylinders have the following dimensions:—

	Diameter.
	Inches.
High-pressure cylinder	19½
Intermediate-pressure cylinder	31
Low-pressure cylinder	51
Stroke of each cylinder	36

The stern tubes are fitted with lignum vitæ; the screw-propellers are made of cast steel; the forward propeller being of 11 feet diameter, and the aft propellers 13 feet, with four blades. There are fifteen single-ended boilers 10 feet 9 inches in diameter and 9 feet long, working at 160 lbs. pressure per square inch, with a total heating surface of 12,400 square feet and four funnels. The builders have guaranteed that the vessel shall be capable of breaking ice 2 feet thick without damage to the structure. As will be observed, this guarantee does not cover damage from ice of any thickness above 2 feet, and such will nevertheless frequently be met with; but no doubt the hull will prove strong enough for its work, even in thicker ice.

The fore propeller had shown important advantages on railway ferry-boats—at least in American waters; but how would it work if applied to an ice-breaker intended to assist other boats in the ice?

The whole question of winter traffic for Finland was submitted by the Finnish Government to a committee, which sat during 1895–96 and made a very complete report on all the matters concerned. Among other business the committee had to work out a programme for a new ice-breaking steamer for the Port of Hangö. After long and careful deliberation, and having taken the views of an expert whom the committee sent to America to report to them on the working of the fore propeller, the conclusion was unanimously arrived at that the American type should be adopted, with such modifications as the special service of this steamer might require. A few extracts from the specification for the construction of this steamer may be of interest. The principal dimensions were to be about 200 feet length, 42 feet breadth and 18 feet draught with full bunkers; water-lines to be curved at the middle, and straight or S-formed at ends; transverse sections to fall out in such a way that the broadest part of the steamer will be above water-line; rudder and propellers to be kept deep below the

water-surface; after-peak (deadwood) to be recessed through; trimming-tanks required fore and aft, with powerful pumps for filling and emptying; material Siemens-Martin steel; Veritas or Lloyd's class to be obtained, but various reinforcements to be made in view of the working in ice; double bottom throughout, and at least five watertight bulkheads; frame distance to be not more than 18 inches; scantlings of stem- and stern-posts, frames and stringers to be of large section; 'tween-deck placed near the water-line to be of iron, wood-covered; upper deck of wood, kept as free as possible from encumbrance; bunkers to hold coal for at least 6 days, running at full speed. In the way of the water-line a thicker plate-belt, 6 feet broad and $\frac{3}{4}$ inch to $\frac{7}{8}$ inch thick, was stipulated, because that part is most exposed to ice-pressure; treble riveting was to be applied to the plates in the way of the stem, stern-post and butts; the plating in the ice-belt was to be flush outside, with longitudinal straps inside to cover the seams. The stem and stern-post was to be provided with a beading for the plate-ends to butt against, as a protection against the ice. The rivet-holes were to be countersunk deeper than usual, and the rivets were to have extra full heads. The engines, of triple-expansion type, were to develop 2,500 HP. in all, and were to be capable of being forced to 3,000 HP. The diameter of the fore propeller was to be about 10 feet 6 inches, and of the aft propeller about 13 feet, leaving the top of the blades 4 feet below the water-surface; the strength of the propeller-shaft was to be 60 per cent. above Lloyd's requirements, and that of all other shafting 35 per cent. more than prescribed by those rules. The circulating water was to be driven by an independent centrifugal pump, and to be taken from a Kingston valve near the keel, from valves near the water-line well forward and abaft, and from two plate-trunks extending from the bottom of the ship to the 'tween deck, the trunks being connected by an iron pipe. This extra provision for the circulating water is desirable when the vessel is among pack-ice, which may stop one or other of the circulating-water inlets. For this reason it is also usual to lead a steam-jet into all the cold-water inlets, for clearing away ice that may clog the openings. The boilers were to have not less than $3\frac{1}{4}$ square feet heating surface per I.HP.

A number of shipbuilding establishments having been called upon to tender, the order was given to Messrs. Armstrong, Whitworth and Company, of Newcastle, in June, 1897; the delivery, having been retarded by the strike, did not take place until October, 1898.

The specification having been drawn as above, the vessel was built in accordance therewith. In Figs. 15 the lines of the boat, the "Sampo," are shown. This, the first ice-breaker in Europe having a screw-propeller in the bow, has now finished her first winter cruise, and, as far as can be gathered, she has demonstrated that this type, already successfully used as ferry-boats, will, with some modifications, do excellently also as ice-breakers.

At Hangö (Finland) there were stationed in the winter of 1898–99 two ice-breakers, the older the "Murtaja" (Fig. 5, Plate 4), of the ordinary type, of 1,200 I.HP., and the "Sampo." The leading commander of these ice-breakers wrote as follows to the Author, on the 13th April, 1899:—

"North and west winds having ruled during the past winter more than ever since the 'Murtaja' came here, the pack-ice has mostly drifted away; further, the winter has been rather mild, and in consequence the solid core-ice has scarcely exceeded 13 inches in places where the ice-breaker has moved. But it has been observed that even a thick layer of snow on the ice has only a very slight influence on the progress of the 'Sampo.' When working in pack-ice this steamer often makes 8- to 10-fathom charges, because this gives better results than alternating directions of rotation of the fore screw, but charges longer than half the ship's length are never attempted.

"On the 11th February we went through a pack-ice belt of 3·5 miles breadth and 5 feet to 8 feet thickness at a speed of about 2 knots in 1 hour 45 minutes without stopping. This work could not have been done by the 'Murtaja' in less than 18 hours of continuous hard work, exhausting the engine-room and stokehold attendants. To judge by comparison, the 'Sampo' ought to be capable of passing, without charging, the thickest core ice ever met with here, viz., 26 inches to 29 inches, even though covered with an equal thickness of snow.

"You will remember my misgivings about the small size of the rudder. Now it is found that the 'Sampo,' in thick ice, with the wind high from starboard, in going forward, has a strong tendency to fall off, port over.

"In working with the 'Murtaja,' it has been proved that the ice is easier to break at low temperature, while a higher temperature causes the ice to offer greater resistance."

In this short account, there are several points of considerable interest:—

(1) A snow cover on the ice presents no appreciable hindrance to this new type of vessel. The objectionable influence of snow has

already been pointed out when speaking of the ice-breaker of the European type. There seems consequently to be a very radical improvement. Instead of allowing the vessel to press the snow forward and to the sides like a snow-plough, the fore propeller washes the snow down and carries it away with the current.

(2) The captain finds he can make better progress by charging than when working in the usual American way—alternating the direction of rotation of the fore propeller. Still there is this difference from the old way of charging with ice-breakers having no fore propeller, that it is possible to back several ship-lengths and to run with full speed against the ice without injury to the boat, but having a propeller right in the fore end, full charge would perhaps introduce some risk.

(3) Plenty of rudder-area is indispensable when working in ice.

(4) Seeing the results of the experiments on the resistance of ice as given above, one is hardly prepared to hear that a steamer goes easier through ice at a low temperature than when the weather is warmer. Still this is the unanimous opinion of navigators in frozen waters, and is doubtless correct, depending on the greater brittleness of ice at low temperature.

In February, 1893, the Author read a Paper before the Russian Imperial Technical Society on "The Possibility of Winter Navigation to St. Petersburg." In this Paper the conclusion was arrived at that winter navigation to St. Petersburg should not be impossible. It is to Admiral Makaroff that the honour is due of having put this suggestion to a practical test. The Minister of Finance having found the money, Admiral Makaroff ordered the ice-breaker "Ermak" from Messrs. Armstrong, Whitworth & Company, and on the 16th March, 1899, she arrived at Kronstadt, met by an enthusiastic crowd on the ice.

The lines of this vessel are very similar to those of the "Sampo," though the "Ermak" is much larger. She is 305 feet long, 71 feet broad and 42 feet 6 inches deep. The ice-belt is 20 feet broad and between $1\frac{1}{4}$ inch and $1\frac{1}{16}$ inch thick, the maximum thickness being amidships. The main frames are spaced at 24 inches, but intermediate frames are fitted in the way of the ice-belt, and web-frames are furnished at intervals between the bulkheads. There are four sets of triple-expansion main engines, driving three screw-propellers aft and one forward. Each shaft is arranged to be disconnected from the main engines and geared to an auxiliary compound engine, the intention being to work only the auxiliary engines when full speed is not required, and thus save fuel. The advantages of this arrangement over the

more simple way of working only one or two main engines is not very apparent, however, and complication in the way of machinery is not desirable in a vessel of this description. The propeller blades are of nickel-steel, and all shafts are 35 per cent. to 60 per cent. stronger than required by Lloyd's. The total power is, according to the contract, 10,000 HP. The boilers are double-ended, placed athwartships, their diameter being 15 feet and their length 20 feet 6 inches. The heating surface is 27,600 square feet, forced draught being used. The stern propellers are 14 feet in diameter, the central propeller having a pitch of 14 feet, and the wing propellers a pitch of 14 feet 6 inches. The forward propeller is 13 feet in diameter, and has a pitch of 13 feet 6 inches. The vessel can carry 3,900 tons of coal, the intention being to take her in the summer to the Kara Sea and Arctic Ocean to test the action of 10,000 HP. on ice and snow of that region. New and most interesting experience will no doubt be gained, and many hearty good wishes will follow the admiral on his way to open the navigation to the great Siberian rivers and to explore the Arctic regions.

On the 5th March, the "Ermak" sailed from the Tyne. Fast ice was met in the Gulf of Finland, between Reval and Hogland, the vessel passing through this without difficulty; but, encountering severe pack-ice, she stuck at times, and had to use the ice-anchors in order to get free, the thickness of the pack-ice being estimated at between 25 feet and 30 feet. It thus took the ship nearly three and a half days to pass from the beginning of the continuous ice to Kronstadt, but during that time the boat was stopped to allow some rest to the crew, which was not up to full strength. Though the end was successfully gained, it is evident that Admiral Makaroff was right in insisting on the power being not less than 10,000 I.HP.

FUTURE ICE-BREAKERS.

The American type of ice-breaker—*i.e.*, with a propeller in the fore end—having certain advantages, will no doubt hereafter be largely adopted; but for regular ice-breakers a modification in the form of the sides will probably be found useful. The American ferry-boats, requiring to be long and to have broad decks, are made with a V-formed middle section, and, seeing that there is no necessity for great displacement, this is a useful form; also, because the ice finds its way below the keel when the vessel is squeezed between two moving ice-fields, and the pressure

on the sides is somewhat diminished. Thus the inclination of the sides has been about 20° from the vertical in the water-line. When builders in Europe began to copy the American type they considered these inclined sides as essential, not only for ferry-boats, but also for ice-breakers. Thus nearly all designs submitted in competition for the "Sampo," by the experienced European ice-breaker builders, showed the sides inclined not far from 20°, as was the case with the design adopted, which had an inclination of 18°. But it should not be forgotten that engineers in Europe have an independent experience of ice-breakers, which clearly indicates that a considerable inclination of the sides is unnecessary. The following Table shows the inclination of the sides of twelve well-known ice-breakers, which have gone through many a hard squeeze in the screw ice without sustaining any serious damage :—

	Inclination.
	°
Ice-boat No. 2, built in 1870 by W. Cramp	0
"Eisbrecher," built in 1871 in Hamburg	10½
"Express," built in 1877 in Oscarshamn at 11 feet draught	0
" " " " 9 " "	5½
"Isbrytaren," built in 1882 at Lindholmen	8
"Starkodder," built in 1883 by Burmeister and Wain	4½
"Bryderen," built in 1884 by Kockum	4½
Danish "Thor," built in 1890 at Lindholmen	6
"Svitzer," built in 1889 at Lindholmen	0
"Murtaja," built in 1890 at Bergsund	10
Norwegian "Thor," built in 1890 at Nylands Works	1½
Nicolajeff "Ledokol," built in 1890 at Lindholmen	3
Libau "Ledokol," built in 1895 at Nylands Works	11

It will be observed that of the above steamers the Libau "Ledokol"—built to the Author's design—has the greatest inclination, viz., 11°, and there certainly seems not sufficient reason to go beyond this. In fact, judging from the above, the average inclination, 5°, should, for all ordinary ice-breakers, answer the purpose.

If greater inclination were obtainable without any sacrifice, there could be no objection to it, but this is far from being the case. The V-shaped midship section means diminished displacement, or rather increase of dimensions to compensate the loss in midship area. But increased dimensions mean increased first cost and inferior handiness in navigation amongst ice, and much inclined sides involve bad sea-going qualities.

Perhaps a slight increase in the scantlings amidships about the water-line would be advisable with the less inclined sides, but this would certainly not amount to so much as the total augmentation

of scantlings prescribed by Lloyd's for the alternative of greater dimensions of the hull. When this is sufficiently appreciated, the more powerful ice-breakers will probably be made in future with a fore propeller according to the American system, but with less inclination of sides amidships, and no doubt with increased engine-power.

The Paper[1] is accompanied by drawings, from which Plate 4 has been prepared.

[1] Since the foregoing was written the "Ermak" has returned from her summer cruise in the Arctic Ocean, where she has not been entirely successful. After an attempt at the ice near Spitzbergen, she was taken back to Newcastle to have more web-frames and longitudinal stringers put in, some new plates replaced and a number of plates re-riveted. One blade of the fore propeller having broken, and the shaft having got out of line, it was decided to remove the fore propeller altogether, and the "Ermak" went on her second trip to force the Arctic ice; but this was hardly more encouraging, and her general seagoing qualities proved to be unsatisfactory, as might have been predicted from her highly inclined sides.

It should be remembered that the power on the fore propeller is only 25 per cent. of the total power, while according to American experience—successfully followed in the "Sampo"—it is desirable to have the power nearly equally divided, or, say, 45 per cent. on the fore propeller. The comparative inefficiency of the "Ermak" may to some extent be explained by this disproportion.

The PRESIDENT, in moving a vote of thanks to the Author, said the members had listened to a very interesting Paper on a somewhat novel subject. From that, as from many other Papers read before the Institution, the members might realize the great breadth of subjects dealt with by the engineering profession. The subject was rather a special one, and it was difficult for those who had not been directly connected with ice-navigation to deal with it. He regretted to learn that several persons who had been expected to take part in the discussion were away from various causes, in some cases, he was afraid, in consequence of illness. He hoped, however, that the Institution would nevertheless receive some observations from them later.

Correspondence.

The Flensburger Schiffsbau-Gesellschaft.

The FLENSBURGER SCHIFFSBAU-GESELLSCHAFT communicated the following particulars of the Weedermann ice-breaking apparatus. This formed a so-called ice-shoe, and consisted of an independent pontoon, of a flattened egg-shaped form, of little depth, and of great breadth in relation to its length. The dimensions of an ice-breaker for an ordinary cargo-steamer up to 36 feet beam were 40 feet by 35 feet by 4 feet deep. The afterpart had a deep wedge-formed gap, into which fitted the bow of the vessel to be protected. By an easily removable apparatus (movable fender) on the wings at the side of the gap, the ice-breaker was tightly fitted to the bow of the vessel; and by means of a steel bracket, to which the stem-post of the steamer was screwed, the ice-breaker was prevented from slipping up or down. It was also made fast to the steamer with steel-wire ropes, etc. The steamer, with the ice-breaker attached, simply charged the ice, which, as a rule, gave way easily; if, however, the ice was particularly thick, the ice-breaker rose up on it, and, being assisted to a large extent by the weight of the steamer to which it was bound, crushed through almost any thickness of ice. The chief advantages of this system were that, as the ice-breaker was much broader than the vessel to which it was attached, there was no possibility of damage to the ship's bow by ice, the mobility of the vessel was not at all affected, and such pontoons could be constructed at a low price in comparison with steam ice-breakers. The s.s. "Sperber," a small vessel of 250 HP., had made several trips on the Schleswig coast with this type of ice-breaker, in a temperature varying between $-4°$ F. and $+5°$ F. Three trips had been made under the following conditions:—(1) Through ice about 11 inches thick the vessel steamed without stoppage about 3 knots an hour; (2) Through ice 12 inches thick the vessel steamed without stoppage at a speed varying between 1 knot and 1½ knot an hour; (3) Through ice between 12 inches and 16 inches thick the vessel had to charge. After each charge she proceeded a distance varying between 43 yards and 54 yards. The ice-breaker and salvage-steamer "Königsberg" had made a trip with this ice-breaker attached, from Pillau into the Frische Haff, with the following results:—In ice 14 inches thick the speed without stoppage was between 1½ knot and 2 knots per hour. In ice 19 inches thick the vessel charged, making a

run varying between 43 yards and 48 yards each time. The channel cut by this ice-breaker was not serpentine, but perfectly straight, which was a matter of great consideration. The captain reported that the pontoon was an excellent protection to his vessel, and that, while charging the ice, which was broken into very small pieces, not the least shaking of the vessel was perceptible. The return voyage was commenced through ice 1 foot 7 inches thick, in which it was necessary to charge six times; after this the vessel returned safely to Pillau. It might be thought that the steering of the steamers would be somewhat hindered by this apparatus, but it was really in no way affected. The "Königsberg" was a vessel about 108 feet long, and of 500 I.HP. During her passage through the ice she was worked with full steam. Up to the present these ice-breakers had been supplied only to vessels of comparatively small size, but they could be constructed to suit the largest steamers, which would be able to crush the thickest ice, provided they were supplied with sufficient motive power. The Flensburger Schiffsbau-Gesellschaft.

Mr. J. GRAVELL, of the Bureau Veritas, pointed out that the question of the power of the fore propeller of the "Ermak" being only a quarter of the combined power of the three after propellers, had nothing to do with any want of success of that vessel in the Arctic ice; and it was found by that experience that for the purpose it would be better for ice-breakers to have no forward propeller, the ice there being much thicker and harder than that which was met with anywhere else. In one case, when the "Ermak" was cutting a channel for herself, she rose up on the ice, and the ice, instead of breaking, tipped and launched the vessel on to the other side, and did so for some considerable time with great rapidity. It was found that for the Arctic regions it was useless to have a forward propeller, although it had been very successfully used in the Baltic ice. Mr. Gravell.

Mr. AXEL VON KNORRING, of Helsingfors, said that as the Author quoted the s.s. "Aegir" as an example of modern steamers for winter navigation further particulars of the working of this ship might be of interest. A short time ago, when cutting her way through the ice outside the lighthouse at Hangö, she encountered very coarse ice, and when backing in this she lost the whole of her rudder and sternpost. Most probably the rudder was at the time pressed hard to one side. The rudder, as well as the stern frame, was of cast steel, and had satisfactorily passed all the tests of the Bureau Veritas; nevertheless they both broke off, without bending, a little below water-level, the sternpost breaking again close Mr. Axel von Knorring.

Mr. Axel von Knorring. to the keel. The ship had not been docked yet, and he was quoting the diver's report. The propeller, although going full speed astern at the time of the accident, was not injured. The engines stopped suddenly, but after a little manœuvring forward and back, worked again as smoothly as before.

The Helsingfors Steamship Company now owned a second winter steamer, similar to the "Aegir" but somewhat larger. This ship, the s.s. "Baltic," was built by the Schiffswerft von Henry Koch of Lübeck and engined by Messrs. Blohm and Voss of Hamburg, and began her first winter campaign in February, 1898. Her principal dimensions were :—

Length on the water-line	200 feet.
Breadth	32 feet.
Depth on the side to main deck	16 feet 6 inches.
Draught with 850 tons load	15 feet.
Loading capacity	58,000 cubic feet.

The engines were triple-expansion, indicating 680 HP., with a boiler-pressure of 200 lbs. per square inch. The power could be increased to 820 HP. for the purpose of forcing ice. In this ship, as well as in the s.s. "Aegir," the engines were designed so that the ship could attain her normal speed in clear water with the most economical coal-consumption. For the purpose of forcing ice, however, the power could be considerably increased, but with a sacrifice of the economy in coal-consumption. It had been considered that this arrangement would give the best economical results, as the time spent in forcing ice was comparatively short, and the waste of fuel for that purpose would therefore be of less importance. Although this had proved to be correct in theory, there was a great drawback to the arrangement. The temptation to run the ship at her highest attainable speed was so strong that it was extremely difficult, notwithstanding strict orders, to induce the captains to confine themselves to the normal speed and engine-power when not forcing ice. As the consumption of coal per I.HP. was increased above the normal by about 20 per cent., the higher speed was attained only at considerable loss of economy. In many instances of course the use of the high speed was quite justified by circumstances, but the temptation to use it always was too great to be resisted.

Mr. Wingfield. Mr. C. H. Wingfield remarked that on p. 112 the Author dealt with the mode in which ice was formed under certain circumstances in the northern seas, and stated that, though fresh water had its greatest density at 4° C., the point of maximum density of salt

water fell more or less below zero,[1] even below the virtual freezing-point of sea-water itself. The Author added that as the water became denser it naturally fell to the bottom, and that on this account,[2] the coldest water being always at the bottom, the time came when, if the water was very still, the whole might get several degrees below the temperature at which it would freeze. A slight shock, the passage of a ship, or anything of that sort, would, if the Author's reasoning was correct, have the result of making the whole of that water become ice, except so much as was warmed above freezing-point by the release of the latent heat of the remainder. Captain G. Caroc, of the Royal Danish Navy, had described to him, in 1887, a somewhat similar phenomenon which was observable in the brackish seas around Denmark. He said the lower layers of water were frequently much colder than those above, and agreed with the Author that they might be, and often were, cooled below freezing-point without congelation taking place until the necessary disturbance arose, but that it then often did so locally. Tufts of seaweed appeared to be sufficient to cause crystallization. They became coated with soft ice, the thickness of which increased[3] till its buoyancy was sufficient to cause it to become detached from the seaweed to which it was anchored. This soft ice was known as "gröd" ice, and had much the same consistency as the "ices" sold in confectioners' shops. It floated up in the form of a ball until, on reaching the surface, it spread into a round disk, which, if the temperature was low enough, froze to hard ice in a very short time. These disks were usually about the size of a dinner-plate, and this kind of ice was known as "tallerken" ice (plate ice) in consequence. By the action of the waves these Mr. Wingfield.

[1] The following Table, drawn up by Mr. F. L. Ekman, might be of interest:—

Per cent. of Saline Matter in Sea-Water.	Freezing Point (Centigrade).	Temperature of Maximum Density (Centigrade).
20·91	−1·1°	−0·44°
25·87	−1·4°	−1·68°
29·99	−1·7°	−2·75°
35·01	−1·9°	−4·00°

[2] Mr. Wingfield thought that the fact of "ground ice" being formed every year in the *fresh* water of the St. Lawrence and other rivers, as well as in the Canadian lakes, showed that the phenomenon was not always attributable to the cause suggested by the Author.

[3] This gradual increase did not seem consistent with the theory of sudden solidifying of infra-cooled water.

Mr. Wingfield. plates were squeezed together, and each froze to its neighbour, producing marks, nearly always found on newly-formed salt-water ice in these seas, like the overlapping tiles on a roof. It often happened that the ice anchored to a large area of seaweed was all on the point of becoming detached, and the least disturbance, such as would be caused by the passage of a vessel, was then sufficient to cause its simultaneous release, as already described. In this case there might not be space for the soft balls of "gröd" ice to spread into "tallerken" ice, and a thick coat of "gröd" ice was formed which gradually froze into a thick layer of hard ice. The effect was somewhat startling. A vessel might at one moment be in clear water, and the next be surrounded by ice. Another proof of the infra-cooled condition of the lower strata of water was the fact that Danish fishermen, after paying out long lengths of fishing-lines so loaded with hooks as to cause them to sink to the bottom, often saw them reappear at the surface so thickly encrusted with ice, which had formed on them and buoyed them up, that their weight was too great to admit of their being safely hauled on board the fishing-boats. Captain Caroc did not offer any explanation of the way in which the lower layers of water became cooled so far below the upper layers. Another gentleman had told Mr. Wingfield that, as a result of carefully studying this subject, he had come to the conclusion that it was a question of diathermancy of the water and the radiation of the bottom; the ground and weed radiated more rapidly than the water, part of the heat was absorbed by the water, which prevented its freezing, and the bottom got colder and colder until it was considerably cooler than the water itself. Ice formed on the cold bottom, and was anchored by the seaweed, &c., until it became so buoyant that a ship passing over it gave it a shake and up it came.[1] A similar result of radiation was seen when on a clear morning hoar frost formed on grass, although the temperature of the air might be many degrees above freezing. The ground lost heat by radiation faster than the air, and condensed and froze the moisture. In a most interesting letter to Mr. Wingfield, Professor Otto Petterson, the eminent Swedish hydrographer, said he thought the radiation hypothesis, which he believed to be due to Professor Nordenskiöld,

[1] Sir Charles Lyell noticed that, in Russia, ground-ice formed most readily when the sky was cloudless; the stones, &c., in the river-beds then parting with their heat by radiation more rapidly than at other times.

Professor Tyndall had pointed out (p. 501 of "Heat a Mode of Motion," 6th edition) that radiation was greatly checked by moisture in the air. This might account for ground-ice being rarely met with except in dry northern latitudes.

was possibly a correct explanation of the formation of ground-ice. His own experience, however, was limited to the formation of ice below the surface, but not at the bottom. This he attributed to currents of salt water, at temperatures below the freezing-point of fresh or brackish water, creeping southwards from polar regions under the fresher water, and freezing those portions of the latter with which they came in contact. Much interesting information on this and kindred subjects would be found in Professor Petterson's "Contributions to the Hydrography of the Siberian Seas," a copy of which Mr. Wingfield had much pleasure in presenting to the library of the Institution. Mr. Wingfield.

The AUTHOR, in reply to the Correspondence, noticed that Mr. Gravell asserted that in the Arctic ice the fore propeller was useless, although it had been effectually used in the Baltic. If this last statement referred to the "Ermak" it was somewhat open to question. According to all accounts, when the "Ermak" had to cope with the pack-ice she was made to charge with a start of several ship-lengths, and this was practised in the Baltic as well as in the Arctic Ocean. This mode of operating was not, as had been shown, in accordance with American practice, and was not without danger to the fore propeller and shaft. If the vessel was to be worked in the European way, by charging, no doubt there should be no fore propeller, either in the Baltic or in the Arctic Ocean; but should the due proportion of power be given to the fore propeller the ship might be worked in the American way with greater advantage. It seemed, therefore, as if the conclusions Mr. Gravell drew were rather hasty and—not being sufficiently supported by arguments—hardly convincing. The fore propeller of the "Ermak" was broken, and the shaft got bent, but did this demonstrate the impracticability of the fore propeller in the Arctic Ocean? The Author ventured to think that charging against the ice at too high a speed would account for the mishap, but he admitted that charging was the only means of getting the desired effect from the 7,500 HP. aft. Again, had the fore propeller carried 4,500 HP., instead of 2,500 HP., there would have been no such need for charging. The Author.

With reference to Mr. Wingfield's remarks, it should be observed that the Author did not speak about the water "falling to the bottom," which in deeper water would not be the case. A most interesting investigation, by Professor Edlund, on the question of the formation of ice, was to be found in the Proceedings of the Swedish Academy of Science.[1]

[1] Öfversigt af Kongl. Vetenskaps Akademiens Förhandlingar, 1862, p. 367; 1863, p. 349; 1865, p. 207.

SECT. II.—OTHER SELECTED PAPERS.

(*Paper No. 3059.*)

"Railway Flood-Works in the Punjab and Sind, relative to the North-Western State Railway."

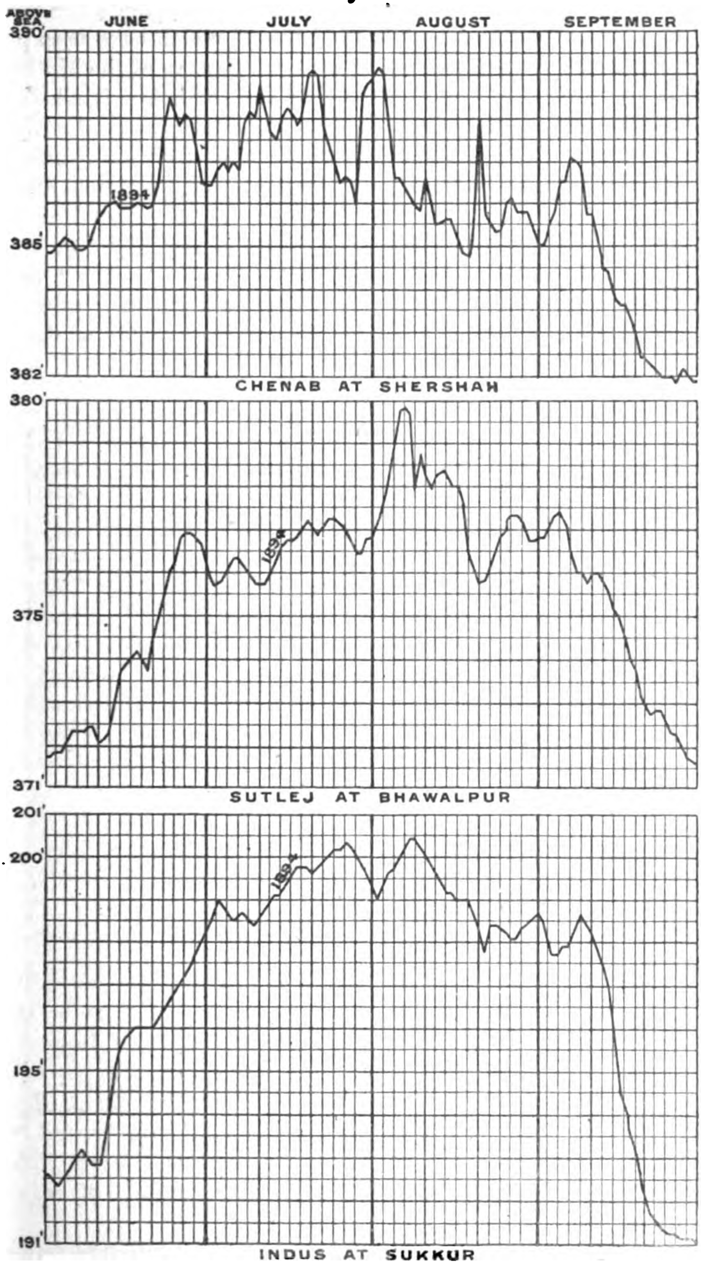
By Richard Craig Farrell, Assoc. M. Inst. C.E.

The Punjab—the Pentapotamia of the Greek historians—is an extensive flat plain, bordered on the north and north-east by the Himalayas, and on the west, immediately beyond the Indus, by the hill ranges of Afghanistan and Baluchistan. To the south and south-east the country is open and flat. The province has an area of about 145,000 square miles, and the great plain forming the larger part of that area is partitioned off by the rivers into large tracts or *doabs*, which form the natural divisions of the province. The name Punjab is derived from the Persian words *panj* (five) and *ab* (water)—the "land of the five waters"—and refers to the chief physical feature of the province, the five rivers.

These rivers lie between the Indus on the west and the Jumna on the east, and are, in succession from the west, the Jhelum, the Chenab, the Ravi, the Bias, and the Sutlej, Fig. 1, Plate 5. Of these the Chenab is the largest and the Ravi the least. (The Indus, the largest of the Punjab rivers, is not considered by the natives as one of the five.) During about eight months of the year, October to May, the broad beds of the rivers lie white and bare in the sun, and seem mere depressions in the surrounding plain; but, in the four remaining months, the heavy rains of the monsoons take effect, and, augmented by the melting of the snow in the hills, the rivers fill the broad channels and inundate the *doabs*. During the cold season, heavy rains in the hills cause occasional floods which do damage to the railway in the vicinity of the upper reaches of the rivers; but they are comparatively trifling and unimportant.

A striking characteristic of Indian railways is their extensive character both in length and in works, and none is more representative in this respect than the North-Western Railway, which, in traversing the Punjab and Sind from the Himalayas to the sea, forms the largest railway system in India under one administration.

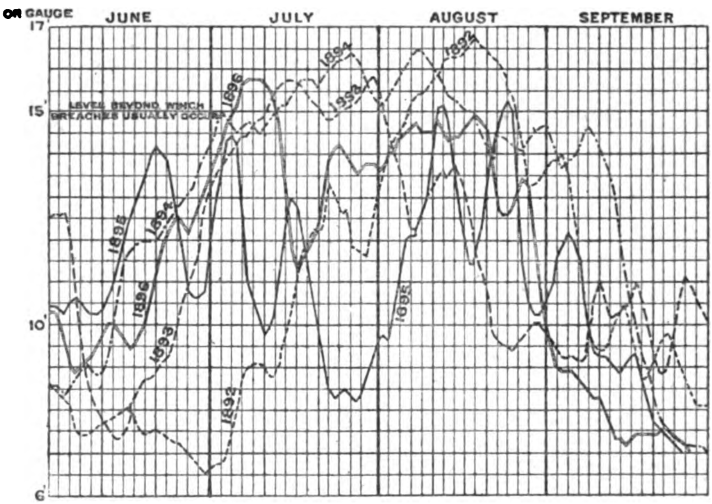
Fig. 2.



RISE AND FALL OF THE RIVERS CHENAB, SUTLEJ AND INDUS.

The railway, as it now exists, is of 5-foot 6-inch gauge throughout, and forms a complete chain, the links of which have been put together from time to time, dating back to the days of the Mutiny. The mileage of the whole, main line and branches (excluding sidings), is 2,834 miles, of which only 108 miles are double line. This length is divided into nine districts or divisions, each of which is in charge of an executive engineer, who has under him one junior executive engineer and two or more (depending on the extent of the division) assistant engineers, each of whom is in charge of a sub-division. The assistant engineers in their turn are supported by the subordinate staff, and all, during floods, are kept busy and constantly on the alert, sometimes night and day.

Fig. 3.



RISE AND FALL OF THE RIVER INDUS AT SUKKUR.

Floods.—Between the 5th June and the 15th June, when the monsoon generally breaks, the rivers begin to rise, due to the melting of the snow in the hills; and between the end of June and the middle of September the level of the rivers fluctuates between 8 feet and 10 feet above the normal cold weather level, *Figs.* 2 and 3. From the 15th September the rivers fall rapidly, and by the beginning of October they are again at normal level. The spurs on the diagrams practically indicate the periods of heavy local rains.

The alluvial nature of the soil renders it peculiarly liable to attack by water, and the floods take effect mainly in two

ways: (1) by scouring out the beds of the rivers; and (2) by washing away the railway embankment. The first action is accentuated, so far as the railway is concerned, where the bridge piers obstruct and split into swirls the even flow of the flood-water. Round the piers the scouring action is enormous, due as much to the permeability of the soil as to the gigantic power of the water, and extends generally to a depth of between 40 feet and 50 feet below normal low-water level. The danger then is that the piers, if not sufficiently deep, are apt to be undermined, with the inevitable result of bringing down the bridge. The second action principally affects the reaches of embankments on the *doabs*, but it is sometimes felt at bridges also, when the river bursts through, or outflanks, the training and protective works in the vicinity of the bridges.

Breaches in the embankment are very frequent during the rainy season and form the greatest source of trouble. The embankments are, of course, made up of the alluvial soil, obtained from borrow pits alongside the line, and are therefore easily disintegrated. The alluvium is in many cases so impregnated with *réh* (saltpetre) that the soil is often literally dissolved if in contact with water. A few hours' rain is often sufficient to breach the line. The rain water, rapidly collecting, rises up against the embankment, and succeeds in a short time, especially if the surface of the water is rippled or agitated by wind, in forming an opening which quickly widens out under the action of the running water, to hundreds of feet, depending on the head and force of the water behind the embankment. The rails and sleepers drop down into the channel thus formed, and the line is effectually blocked to the running of trains. The floods of 1892 were fairly representative, and a brief account of their effects in the Karachi district alone will serve to indicate the general nature and tendency of the floods, and the work entailed during flood periods.

Heavy rain began to fall between Karachi and Kotri on the 10th July, and continued more or less heavily till the 16th, 11 inches in all having fallen. Early on the 13th the down-stream wing-walls of the bridge (two 12-foot arches) at 46 miles gave way while a heavy flood, with an afflux of about 2 feet, was rushing through the bridge and scouring out the foundations. Later on, the down-stream half of the pier fell, carrying the two arches with it almost entirely, but leaving sufficient of the abutments to serve as abutments for a temporary bridge. The line was therefore blocked to the passage of trains. On the 14th and 15th, repairs were carried out by throwing in pitching stone, and,

during the lulls in the storm, a sleeper crib pier was erected and beams were placed across to span the opening. Communication was restored on the afternoon of the 16th July. Trouble was also experienced between Ranpethani and 51 miles, and over a length of ½ mile near Bandiwalli and ½ mile near Pipri. The line in these places is designed to pass the water over the bank in the manner described later, and is graded low, with the embankment pitched with stone; but, in spite of that, small breaches occurred, causing more or less interruption, until more stone was put down. On the 26th July the bridge at 46 miles was again reported unsafe for the passage of trains, and transhipment was resorted to. On the same date a deviation was started, the flood channel being crossed by one span of 20-foot iron girders placed on abutments built of sleepers. Heavy hill floods on the nights of the 25th and 26th July washed out the ballast in five places between Ranpethani and Bholari, causing detention of the trains between Karachi and Kotri; there were no actual breaches, and ordinary traffic was resumed on the 27th. On the 6th August a severe rainstorm raged between Kotri and Radhan, damaging the line very seriously. The line all the way from Manjhand to Bubak (52 miles) was in a more or less precarious condition from soft banks and erosion of slopes. The following is a list of actual breaches between Sann and Laki:—

(1) Near 168 miles, it was found that the bank had completely disappeared, a stream 3 feet to 4 feet deep passing through the breach with considerable velocity, and the line was impassable even for a trolley.

(2) Near 175 miles, a length of 250 feet of the embankment was completely washed away behind both abutments of bridge No. 433. The bridge, however, stood well.

(3) At 176 miles, the line was breached for 130 feet behind one abutment of bridge No. 437. This bridge also stood.

(4) Near 177 miles, four complete breaches of one or two rail lengths each, were formed.

(5) At 179 miles, the bank was completely washed out for a length of about 30 feet in each of two places.

(6) At 181 miles, the bank behind the abutments of bridge 455 was washed away, leaving the bridge standing.

In addition to these actual breaks, the remainder of the line was absolutely unsafe between Sann and Bubak, and traffic had to be reduced. It subsequently became necessary to block the line to all traffic with the exception of a single convoy of trolleys carrying mails, so as to enable "stone" trains to run, in order that the

breaches might be filled up. It was dangerous to attempt running trolleys with passengers, on account of the numerous "stone" trains, but every effort was made to get the first- and second-class passengers taken over the breaks, and they were carried by "stone" trains part of the way. The third-class passengers (natives) were taken in boats on the river between Laki and Sann. The line between Bubak and Sehwan was repaired on the 8th. On the 10th the line between Sehwan and Laki was repaired, and communication was restored. On the 14th, communication between Sann and Amri was restored and the mail train was allowed to go through on the 16th. Other breaches were also repaired and communication between Sann and Bubak was fully restored, the speed of trains over the length being restricted to 10 miles an hour till the weather cleared up.

Scarcely had that work been done when a new source of anxiety arose, by the line being breached, on the 17th, in two places at 247 miles, between Radhan and Sita. Owing to the abnormal rise of the Indus and the subsequent inundation of the country around, to the overflowing of the Pritchard and Joungwah Canals, and to the failure of the Magsie and Nangeshah bunds, the water headed up against the railway embankments, causing several breaches. The breaches at 247 miles were about 150 feet long in a bank of 6 feet. The engine of a stone train, which happened to be running at the time of the breaching, fell into one of the gaps, completely destroying the permanent way. The flood was running fast, and traffic had again to be suspended. On the 18th, the line between Sita and Phulji was breached at 241 miles, the breach being 300 feet long. A temporary bridge of forty spans of 10 feet was erected to span the gap. The flood-water, rising rapidly, prevented any efforts being made to close the gap at 247 miles. The water was therefore allowed to pass, and waterways with 20-foot girders were provided. On the 19th there was another breach near 247 miles, making in all five breaches between 241 miles and 247 miles, four breaches being in the vicinity of 247 miles. On the 20th there was no abatement in the flood, and a deviation of the line was begun, the flood discharge streams being spanned by girders on 10-foot openings. Subsidence of the flood began on the 24th, and by the 30th August through communication was restored.

The Protection of the Railway.—Protection works are only provided in the vicinity of bridges. No actual protection is, or can be, in a financial sense, afforded to the reaches of embankment traversing the *doabs*, as, in those lengths, falling rain and the consequent heading up of the water behind the embankment, is

the chief disturbing factor. Grass, as turf, cannot be got to grow in these practically arid tracts. Indirect protection, if it may so be called, is given to the length of bank as a whole by the provision of flood openings which allow the water accumulating on the up-country side of the bank to spill out down-country, thereby reducing the pressure of water against the bank. These flood openings have been built from time to time since the railway was first constructed, the location of the various sites being fixed by accumulated experience of the requirements of the floods. The openings are entirely distinct, as a class, from openings provided for natural water-courses, and are only in use during the rains.

In Figs. 4 and 5, Plate 5, are shown drawings of typical openings to pass flood-water. The main features of these openings are the provisions for preventing the scouring out of the bed and for protecting the bank by stone or brick pitching in the immediate vicinity of the abutments. These designs, although simple and involving no special construction, are the outcome of experience in dealing with floods, and they are found to answer the purpose admirably. The drop-walls at the outer edges of the stone flooring are necessities in many cases, as they prevent the water cutting in under the pitched floor on the up-stream side, and resist the suction of the flow on the down-stream side, the latter action being more to be feared than that up-stream. The floors protect the founds, but the pitching requires to be repaired after each flood season. In many cases, depending on the manner and direction in which the flood current approaches these spill-bridges, it is necessary to protect the flanks of the bridges by erecting small earthen embankments faced with stone (or, as they are called in the Punjab, "wing-bunds"), which also train the current through the opening. On the up-stream side, the most active lines of influx are along the railway embankment, and therefore a right-angled turn at the outer end of the wing-wall of the bridge is necessitated. The tendency is, therefore, to increase the erosive action on the embankment in the immediate vicinity of the wing-wall. In addition to this, a swirl or whirlpool is formed just behind the end of the wing-wall, and is a very active agent in destroying stone pitching on the embankment. To prevent the washing out of the embankment, it is necessary to reduce the swirls by rounding off the corners at the ends of the wing-walls, and also to keep the vortices as far away as possible from the bridge. A preliminary work which is sometimes carried out is that of connecting the borrow-pits in the immediate vicinity

of the bridge to form one trench. That trench is intended to offer a preferential line of approach to that offered by the railway embankment, and it is assisted by cutting a cross trench in the direction of the opening. The next and main process is to erect earthen wing-bunds, flanking each abutment, *Fig. 6.* The wings splay outwards from the bridge to give increased waterway, and then curve out to the inner line of the borrow-pits, whence they are returned by easy ogee curves to the line of the embankment. The part of the wing facing the "funnel" is usually built more strongly than the remainder (with clay if procurable), and is more heavily faced with stone, the slope being 1 to 1. The ogee is also faced with stone, and the slope is 2 to 1.

The effect of the bunds is to intensify the influx at the centre line of the bridge, and care has to be taken to have the floor thoroughly well pitched and protected against scour. On the down-stream side, the water is shot out of the opening and digs

Fig. 6.

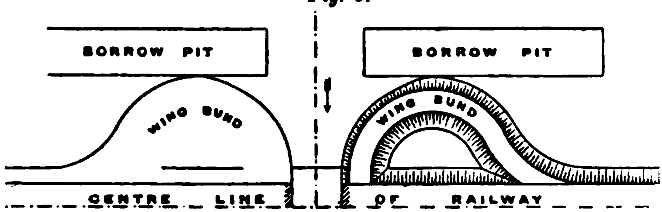


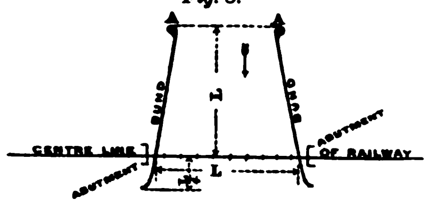
DIAGRAM PLAN OF WING-BUNDS.

out a pit in the soft soil, and, if that is not protected, the water gradually eats back to the bridge and undermines it. The difficulty is got over by pitching the floor for a considerable distance (depending on the velocity and power of the stream) out from the bridge, and by erecting wing-bunds similar to those up-stream, which spread the water, while protecting the railway embankment at the same time. On secondary or unimportant branch lines, where it is not desirable to go to the expense of erecting flood openings, another and simpler method is adopted to pass the flood-water without damage to the railway, Figs. 7, Plate 5. The grade of the railway is lowered into a hollow or dip, and the embankment thus formed below flood-level is pitched completely, top and slopes, with stone. The depth of dip is fixed at 18 inches, *i.e.*, 18 inches from normal flood-level to rail-level, as beyond that depth the locomotive fires would be extinguished. The depth being fixed, the length of the depression or dip is varied to suit the volume of flood-discharge at the

site. Provision is not made at these dips for extraordinary floods. The bank and ballast are protected by hand-set rubble stone 18 inches thick. Such pitching naturally requires repair after floods, but it serves its purpose in saving the bank during the flood. The foregoing are minor flood-works, but they are so numerous on the railway that, in the aggregate, they represent a very large outlay in first cost and maintenance.

The real work of protection—protection of any magnitude—occurs where the railway crosses the main rivers of the province, or where the rivers run in close proximity and parallel to the alignment of the railway. At the river crossings the nature of the work may be divided into (*a*) training, and (*b*) protection works. They are generally done together in a combined scheme, but economical considerations sometimes permit only of protection, and not training, methods being adopted. Both protection and training are obtained by means of earthen bunds thrown up with

Fig. 8.



PLAN SHOWING CONTINUOUS BUNDS.

their tops above flood-level, and faced or unfaced, as the case may be, with stone. Training works always require stone pitching, while bunds, purely for protection purposes, may often stand without stone facing. Protection works generally take the form of bunds thrown diagonally across country between river and railway bank, and training works are usually aligned at an angle approaching 90° with the alignment of the railway on the up-stream side. Two systems have been adopted with success in training a river towards the railway bridge:—

(1) By forming continuous bunds on either bank, extending directly up-stream.

(2) By forming spur bunds or groynes and throwing them out at right angles to the current of the river.

The continuous bund system is most effective when it can be planned as shown in *Fig. 8*, but conditions of site very seldom favour the symmetrical, or even unsymmetrical, convergence of the bunds up-stream. The tendency of a Punjab river, generally,

is to form into narrow channels between two or more of the piers of the long bridge which is necessary to span the river. The converging shape of the bunds acts in such a way that it collects and gathers the river together at AA, and then spreads it out gradually, causing it to occupy the whole waterway of the bridge. Where there is no solid ground on which the heads AA of the bunds can rest, it is the practice to make the up-stream length of the bund at least equal to L, the full span of the bridge. On the down-stream side, one-fourth of L is found a sufficient length to counteract the eddy scours which act immediately on the down-stream side of the abutments. The width AA depends on the number of piers in the bridge. The piers so divide and obstruct the waterway that a much narrower width at AA gives a larger effective channel than that afforded by the bridge. The bund is represented in cross-section in *Fig. 9.*

The depth to which the scouring action of the river extends is the main factor in determining the dimensions and quantity of

Fig. 9.

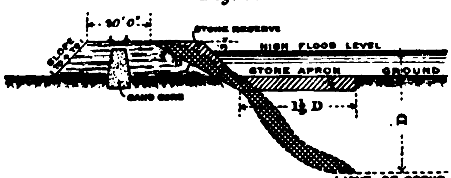


DIAGRAM OF CROSS-SECTION OF BUND.

the stone protection. After the bund has been set out, the apron trench is dug to a width from toe of slope at low, or subsoil, water-level, equal to $1\frac{1}{2}$ times the maximum depth of scour. The bund is made wholly from the trench excavation, but, in cases of high bunds, if more earth is required, it is always taken from the river side of the bund, as any excavation at the back of the bund tends to cause the river to "blow." When the apron trench yields more material than is necessary to bring the bund up to normal section, the width of the bund towards the back is increased till bund and excavation balance. The core of the bund is made up of good sand, and the slopes, where possible, of clay, the back slope being planted (where they can be got to grow) with willows, elephant-grass, or other deep-rooted vegetation, as a protection against the effect of lapping wavelets formed on the water which gathers, behind the bund, by spill above AA, or by percolation. In many cases the area behind the bund is purposely filled with water, let in by a controlled sluice-gate in the bund.

This reduces the pressure on, and percolation through, the bund from the river side, and in time the area becomes silted up; the more quickly when a high-level outlet is given to draw off the clear upper water, thus enabling a steady inflow of river water, carrying silt in suspension, to be admitted. The thickness of the horizontal apron is 4 feet, so that its area in terms of D is 5 D square feet. The total amount of stone put down at first is, in cross-sectional area, D × 8, so that D × 3 is the area of stone reserve which is banked up on the river face of the bund, at as steep a slope as it will stand—usually about 1 to 1. The top of the bund carries a tramway by means of which, during floods, reserve stone can be carried at once to threatened portions of the bund. In *Fig. 9*, the portion cross-hatched shows the ultimate position of the protection stone after the scouring out has taken place. As the bed becomes scoured out, the stone apron gradually sinks and forms a stone face to the new slope formed below ground-level, and thus prevents the undermining of the bund.

With regard to the spur-bund system of training, a description of the existing works on the Chenab River—at the Alexandra Bridge, Wazirabad—which are typical, will illustrate the designs and methods adopted. The system was devised to force the rivers to silt up their banks into a training line, instead of forming erosive bends in them to the ultimate detriment of the railway. First, in reference to the bridge itself, the chief desideratum is, apart from amplitude of waterway, to have the bottom of the wells, on which the piers are founded, well below the maximum depth of river scour. The Alexandra Bridge is an evidence of the change in engineering opinion on the subject of the amount of waterway to provide. Earlier engineers favoured the throwing across of very long bridges, to span, at least, the broadest demarcation of the river channel. The Alexandra Bridge was first built of sixty-five spans of 133½ feet, but the number was reduced between the years 1880 and 1885 to twenty-eight, by dismantling and filling up sixteen spans on the right bank, and twenty-one spans on the left bank. The effective waterway is, however, only of twenty-six spans, as the two end spans are occupied by flank protection works. At the same time the river was trained towards the bridge so as to confine it within the narrowed limits. Experience has shown that the earlier bridges are generally too long, while their spans are individually too short. It has been found easier to confine the river in large spans than to spread it in comparatively small ones. The earlier efforts were apparently directed with a view to giving the rivers room to spread out

and so reduce their force and scouring action; but the rivers will not so spread of their own accord, their tendency being all in the direction of forming comparatively narrow channels. Even in floods, it is not an unknown occurrence to have the rivers rushing down through certain spans of the bridge, then up again diagonally and finally down again. With a shorter bridge and training works it naturally follows that the scouring action of the river is increased, and this has to be guarded against. No flooring is laid down under the bridge, and the scour of the river is allowed to work itself out except in the vicinity of the piers. The scouring action is greatest just round the piers, due to the swirls and eddies caused by the obstruction of the current, and it is necessary to throw in stone round the piers. The scour hole takes the shape of an inverted cone. During the cold weather, or before floods come on, large quantities of stone are piled up around the piers, so that when scouring begins the stone gradually sinks and, lining the scour hole, prevents undermining (this is similar to the action of the apron stone at wing-bunds). In addition to this, during severe or heavy floods, it is necessary to throw in large-sized stone around the piers frequently—at some bridges almost daily—while the flood lasts. At the bridge itself nothing is done except to connect the training works to the abutments. In Fig. 10, Plate 5, is shown a general plan of the Alexandra Bridge and the training works leading down to it.

The Haripur bund, erected on the left bank in 1872, was the first protection and training work put up. Its purpose was mainly to block up the old Wazirabad channel of the Chenab, and to prevent the Pulku Nulla from being filled with spill water from that river. It also acted as a protection to the railway embankment between Wazirabad and the river-bank. The banks of the river as they were in 1880 are shown by a dotted line on the plan, Fig. 10, Plate 5. Between 1880 and 1885 a continuous series of spur-bunds was erected; the bunds on the right bank were made long and were placed at considerable intervals, while those on the left bank were made short and were placed close together, on account of the direction of the current. The main channel of the river had a decided trend towards the left bank, and it was on that side that training was more required. A glance at the position of the banks of the river, as now existing (shown in full lines on the plan), will show at once the effect of the spur-bunds. On striking the first spur, the water is thrown in-stream, and a back current is induced behind the spur, where the water is practically trapped, and is forced to deposit its silt.

Before the stream has recovered from the interruption to its even flow caused by the first spur, it encounters the second spur and the process of silt depositing is continued in the calm water behind the bund. This occurs all down the line to the bridge, and the stream is so constantly thrown towards its centre that it has little opportunity to eat into the bank between the spur bunds, where, moreover, the practically calm water acts as a buffer; but it has been found necessary to supplement certain of the spurs by connecting their landward ends with a bund, Fig. 10, Plate 5.

A considerable amount of land has thus been reclaimed, and the river has been turned, at a fairly abrupt angle, from its direct course. As a natural consequence of throwing direct opposition in the way of the current, the spurs suffer severely during floods, and have to undergo considerable repairs year by year. This class of bund requires, necessarily, to be stronger than that which runs in a direction parallel to the course of the river. The heads projecting into the stream suffer most, and are given additional strength by forming round them a massive facing of stone blocks, outside of which, and round the base, large masses of trees and brushwood are tied together and anchored, Figs. 11 and 12, Plate 5. The bunds act in a very satisfactory manner, and, now that they have a thorough hold on the site, little trouble, comparatively speaking, is experienced. The training works extend about 3½ miles up-stream and ½ mile down-stream.

The cost of repairs—and works under the revenue head of accounts—necessitated by the floods, is (taking the average for the last 7 years) about four lakhs of rupees, annually, over the whole line.

In conclusion, the Author desires to express his indebtedness to Mr. H. L. Monk, M. Inst. C.E., Officiating Engineer-in-Chief, and to Mr. G. Humfress, M. Inst. C.E., Superintending Engineer, for permission kindly accorded to make this communication; also to Mr. G. H. List, M. Inst. C.E., Engineer-in-Chief (on furlough), and to Mr. J. R. Bell, M. Inst. C.E., late Consulting Engineer to the Government of India, whose reports have been utilized in preparing the Paper.

The Paper is accompanied by four tracings and two drawings, from which Plate 5 and the Figures in the text have been prepared.

(*Paper No. 3116.*)

"Selangor Government Railway."

By Guilherme Henrique Fox, Assoc. M. Inst. C.E.

The State of Selangor is one of a federation of four Malay States under British protection, namely, Perak, Selangor, Pahang, and Negri Sembilan, occupying the greater part of the Malay Peninsula, Fig. 1, Plate 6. It is situated between parallels 2° 40′ and 4° north latitude and between 100° 40′ and 102° east longitude, and has an estimated area of 3,500 square miles and a coast-line 110 miles long. The principal industries are tin mining and coffee planting, from the former of which at present it derives most of its revenue. The exports are tin, coffee, gambier, pepper, gold, tapioca, gutta, &c.; the imports are rice and other food supplies, opium, &c. The population, mostly Chinese, is estimated at 175,000. In 1897 the revenue of the State was estimated at $3,750,000,[1] the expenditure at $3,000,000, and the value of the export and import trade at $22,000,000.

A single line of metre gauge railway, the property of the State, constructed and worked by the State, connects the western, northern, and southern districts with the capital and the coast. The west or coast section of the railway, 27 miles long, commencing at Kuala Klang, the port of the State, at the mouth of the Klang River, runs in an easterly direction along the valley of that river into the interior, and terminates at Kuala Lumpur, the capital. The country traversed is flat, and with the exception of the erection of a 100-foot span bridge over a tidal creek and a viaduct 473 feet long in four main spans of 100 feet over the Klang River, for both of which cylinders had to be sunk, 96 feet and 77 feet respectively below rail-level, for a foundation, the construction presented no engineering difficulties. The principal items of construction were: Earthwork 830,000 cubic yards; sixty

[1] $1 may be taken as equivalent to 2*s.* at the present time.

bridges and culverts 7,000 cubic yards. The total cost, exclusive of rolling stock, was $1,064,000, or $39,400 per mile.

The north section, 38 miles long, runs from Kuala Lumpur in a northerly direction towards the watershed of the Selangor River, and terminates at Kuala Kubu, the principal town of the northern district of the State. The country traversed is of a rough nature, Figs. 2, Plate 6, and owing to the alignment being parallel to the main range of mountains, running in a northerly and southerly direction along the eastern boundary of the State, and consequently at right angles to the principal valleys, heavy cuttings and embankments had to be constructed to cross the spurs and valleys springing from it. With this exception the construction presented no difficulties. The principal items of construction were: Earthwork 2,571,476 cubic yards; seventy-six bridges and culverts 12,655 cubic yards. The section, exclusive of rolling stock, cost $1,769,196, or $46,558 per mile.

The south section, 17 miles long, also commences at Kuala Lumpur, and runs in a southerly direction partially along the valley of the Langat River to Kajang. The country traversed is flat, Figs. 2, Plate 6, and with the exception of the construction of a bridge founded on cylinders, presented no difficulties requiring comment. The principal items of construction were: Earthwork 660,000 cubic yards; thirty-seven bridges and culverts 5,100 cubic yards. Exclusive of rolling stock the section cost $657,000, or $38,650 per mile.

Kuala Klang Harbour, the port of the State and the coast terminus of the railway, is situated at the mouth of the River Klang, where it debouches into the Klang Straits. Being landlocked, it affords excellent anchorage for vessels of deep draught, and as a harbour it compares favourably with New Harbour, Singapore, north of which it is the finest harbour on the west coast, and from its geographical position the best natural port on the western littoral of the Peninsula. The wharves, owing to the soft nature of the sea-bottom and the difficulty in getting suitable timber to resist the attacks of the *teredo navalis*, are constructed entirely of iron, the superstructure of which is carried on cast-iron cylinders. The work, when completed, is estimated to cost $850,000.

Surveys for Extensions.—Surveys have been made for the extension of the system northwards and southwards towards Perak and Negri Sembilan respectively, to connect with the railways of these States, and these extensions are now under construction. A further project for the extension of the railway system into the

State of Pahang, on the east coast, will, when completed, open up a large extent of country rich in mineral wealth which up till now, owing to difficulties of transport, has remained largely undeveloped. On the completion of these extensions the Malay Peninsula will be traversed by a trunk line running south from Kuala Prai on the mainland, opposite to Penang, to Seremban in Negri Sembilan, and by a branch line connecting the interior of Pahang with the west coast. It is expected that a very large proportion of the traffic of the federated Malay States will pass over the Selangor Government Railway.

WORKS.

Earthwork.—The formations of cuttings and embankments are constructed to a width of 18 feet and 16 feet respectively, with slopes varying between $\frac{3}{4}$ and $1\frac{1}{2}$ to 1 in the former and $1\frac{1}{2}$ to 1 in the latter. As is usual in countries where the cost of transporting plant is prohibitive, the material from cuttings beyond a lead of a few hundred feet is thrown to spoil, and the embankments are made up from side cuttings. Manual labour with the hoe and basket was employed throughout, one coolie shifting in a day between 2 cubic yards and 6 cubic yards, at a cost varying between 12 cents and 40 cents per cubic yard for soft, and between 75 cents and $2 per cubic yard for rock. The slopes of cuttings are turfed, as, owing to erosion by rain, grass cannot grow from seed. The turfs are cut into pieces 12 inches square, and are fixed in position by light pegs 6 inches long, the whole when laid costing 15 cents per square yard. It has not been found necessary to turf slopes of embankments.

Bridges and Culverts.—With the exception of some iron-tube culverts constructed on the coast section and bridges resting on cast-iron cylinder piers, the abutments of all waterways are built of brick in cement, the cost of which varies between $9 and $13 per cubic yard. The iron-tube culverts are of wrought iron constructed in segments 6 feet long by 6 feet in diameter. The tubes rest on a concrete flooring, floated on a foundation of mangrove piles 8 inches in diameter, 30 feet long, and driven at 18 inches centres. On the outside the ironwork is protected with a coating of pitch, inside with tar. Completed, these culverts cost $71 per lineal foot. The foundations of all bridges are of the usual type. For deep foundations cast-iron cylinders, varying in diameter between 7 feet and 6 feet 6 inches at the bottom and tapering to 5 feet 6 inches, have been sunk, in some cases 96 feet

below rail-level. The cylinders are cast in three segments 6 feet deep, of metal 1 inch thick, which, when bolted together and fixed in position, make up the pier. Sinking is performed from pontoons where staging cannot be used, the grab being employed for excavation in the wet. The cylinders, when sunk to their foundations, are tested with a load of 50 tons, and on proving satisfactory under the test, the foundations are filled with concrete. The average daily progress for excavation was 1·6 foot, for concreting 3·2 feet, the cost of cylinders, including sinking and concreting, varying between $60 and $80 per foot.

Permanent Way.—The permanent way consists of flat-bottomed steel rails 24 feet long, weighing 46½ lbs., and on the newer sections 60 lbs., per lineal yard, the heavier rail having recently been adopted to meet the requirements of the increased traffic. They are fixed by spikes and fang bolts to square dressed hard wood sleepers, 6 feet 6 inches by 9 inches by 4½ inches, 1,980 to the mile. The ballast is laterite (a form of argillaceous ironstone), gravel, or coarse sand, spread 6 inches under and up to the surface of the sleepers. Where sand is used a boxing of laterite is laid on the outside to prevent the sand being washed away. Sleepers obtained locally cost between 64 cents and 75 cents each, their lives varying between 5 years and 8 years. Ballast costs between 20 cents per cubic yard for sand and $1·50 for laterite, and platelaying between 70 cents and $1 per lineal yard. The permanent way complete costs between $9,400 per mile for 46½-lb. rails and $13,800 for 60-lb. rails.

Stations and Buildings.—Stations and buildings are constructed where required, and at distances varying between 5 miles and 7 miles apart. All stations have double lines, the loop being 1,000 feet long. The platforms are 400 feet long, 15 feet to 20 feet wide, and raised 2 feet above rail-level. The station buildings are substantially built in brick or wood and roofed with tiles, the accommodation provided in the wayside stations being booking-hall, waiting-rooms, and station-master's quarters. Goods sheds at roadside stations vary in length between 60 feet and 100 feet, and are 25 feet wide. The frames are of hard wood, the roof principals of iron, and the sides and roof of 24 B.W.G. corrugated iron. The cost of an intermediate station varies between $3,000 and $25,000.

Telegraph.—The telegraph lines are laid on Siemens No. 500 S steel poles, twenty-two to the mile. They are supplied in three parts, and when erected stand 16 feet above ground. The wires are of phosphor bronze, and weigh 1 cwt. to the mile. The lines

laid cost between $350 and $400 per mile. The Postal Department of the State have the use of the poles for their wires, the maintenance of poles and all wires remaining in the hands of the Railway Department.

Materials.—With the exception of articles manufactured in Europe, such as rails, girders, cement, &c., all the materials required for construction were procured locally. Clay for bricks is found nearly everywhere, and advantage was taken of this to manufacture bricks along the line side. The bricks were of the usual size, 9 inches by 4½ inches by 3 inches, and of a fair quality, and cost between $50 and $80 per 10,000. The following are the hard wood timbers used in the construction of permanent structures: Bilian, balau, daru (*Apodytes* species), petaling, merbau (*Afzelia palembanica*), rengas, tampenis (*Sloetia sideroxylon*), and tembusu. The soft timbers are numerous, but can only be used for temporary structures, as they are liable to destruction by white ants and dry rot.

Labour.—The usual labour difficulties experienced in sparsely populated countries are felt here. The greater portion of labour is imported from China and Southern India. All heavy work is performed by Chinese, who are the navvies of the Far East. Wages vary between 30 cents and 50 cents for Chinese labour and between 25 cents and 32 cents for Indian labour, the quantity of work turned out by the former being to the latter in the ratio of their wages.

DETAILS OF CONSTRUCTION.

Item.	West Section.	North Section.	South Section.
Average cost per mile, exclusive of rolling stock $	39,400	46,558	38,600
Cost of construction in terms of earthwork per cubic yard . . . . $	1·28	0·68	0·99
Quantity of earthwork per mile . . cubic yards	30,740	67,670	38,888
Cost of ,, ,, ... $	11,000	24,267	9,000
Number of bridges ,, ...	2¼	2	2¼
Cost of ,, ,, ... $	10,000	6,000	11,000
Quantity of masonry ,, . . . cubic yards	260	333	300
Cost of permanent way ,, ... $	9,460	9,496	12,037
Number of stations	5	5	6
Cost of stations per mile . . . . $	4,000	4,250	4,800
Cost of telegraph ,, ... $	..	360	400

ROLLING STOCK.

Locomotives.—The locomotives are principally of two types, the goods engines having six coupled 3-foot 6-inch wheels, Figs. 8,

Plate 6, and the passenger engines four coupled 4-foot 3-inch wheels. They are 41 feet long over the buffers, with a wheel-base 33 feet 3¾ inches, and weigh, in working order, 42 tons. They are provided with a four-wheeled bogie in front and a four-wheeled tender. The cylinders are placed outside, and the running speed with full loads on the level is 25 miles an hour, but they are designed to run at higher speeds when necessary. The tenders have water-tanks with a capacity of 1,000 gallons and a fuel stowage of 250 cubic feet. The fuel used is wood. All wheels, with the exception of those on the bogie, are fitted with brakes which can be worked either by steam or hand. The following are the principal dimensions:—

Cylinders	14 inches in diameter with 20 inches stroke of piston.	
Coupled wheels on tread	3 feet 3 inches diameter on	goods,
	4 „ 3 „ „	passenger.
Bogie wheels „	1 foot 11 „ „	goods,
	2 feet 3 „ „	passenger.
Tender „ „	2 „ 9 „ „	goods,
	2 „ 9 „ „	passenger.
Engine wheel-base	17 „ 8¼ „ „	goods,
	18 „ 10 „ „	passenger.
Rigid „ „	8 „ 9 „ „	goods,
	7 „ 0 „ „	passenger.
Bogie „ „	4 „ 9 „ „	goods,
	5 „ 0 „ „	passenger.
Tender „ „	7 „ 0 „ „	goods,
	7 „ 0 „ „	passenger.
Engine and tender wheel-base	33 „ 3¾ „ „	goods,
	33 „ 3¾ „ „	passenger.
Heating surface in tubes	616·0 square feet on	goods,
	608·5 „ „	passenger.
„ „ firebox	72·0 „ „	goods,
	66·0 „ „	passenger.
Total heating surface	688·0 „ „	goods,
	674·5 „ „	passenger.
Grate area	12·5 „ „	goods,
	12·25 „ „	passenger.

Carriage Stock.—The first and second class are composite carriages of the bogie type, Figs. 3, Plate 6; they are 45 feet long over the end platforms. The bodies are 40 feet by 7 feet 4 inches in inside dimensions, 6 feet 9½ inches high at centres, and 6 feet 3 inches at sides. The main woodwork is of teak, with side panels of 16 B.W.G. sheet-iron. The interior fittings are of modern design, and the seats are cushioned with buffalo-hide and hair. They accommodate thirty-seven passengers, and weigh when unloaded 12½ tons. The third-class carriages have the same principal dimensions as the first class, Figs. 4, Plate 6. The internal fittings are

of pine, painted, and grained oak. The seats are placed back to back, transversely, with a central passage from end to end. They accommodate eighty passengers and weigh unloaded 12½ tons. The under and upper roofs of all carriages are of pine, with the exception of the third class, which have corrugated iron upper roofs. The entrances are at the ends, the platforms being protected with railings and side gates. The bogies, one at each end, are four-wheeled, 9 feet long over the headstock and 5 feet 1⅝ inch over the soles. They have safety straps fixed to them as a protection against failure of the suspending gear. The wheels are 2 feet in diameter on the tread. Roof lamps burning oil are fitted to all carriages. The passenger brake vans are 19 feet long over the end platforms; the bodies are 14 feet 6 inches by 7 feet 4 inches in outside dimensions. They are mounted on four wheels having a wheel-base of 9 feet 10 inches. Each van is fitted with a hand-brake gear worked from the inside and weighs 8 tons.

Goods Stock.—The goods stock consists of covered and uncovered trucks, lowsides, cattle and timber wagons, the covered trucks being of two types, four-wheeled and bogie. The four-wheeled covered trucks, Figs. 5, Plate 6, are 14 feet 6 inches long by 7 feet wide in outside dimensions, and are 6 feet 3 inches high at the centre from top of floor to underside of roof. They are fitted with sliding doors on both sides, the opening of which is 4 feet 4 inches. The sides and ends are of timber 1 inch thick, and the roof is of galvanized iron. The underframes are of steel and are mounted on wheels 2 feet in diameter on a wheel-base 8 feet long. They weigh 3½ tons and carry a load of 5 tons. The bogie covered wagons, Figs. 6, Plate 6, measure 32 feet by 7 feet and are 6 feet 3 inches high at the centre; three sliding doors are provided on each side, with openings 4 feet 4 inches wide. The sides, ends, and roofs are built of the same class of materials and of the same scantlings as the four-wheeled stock. The bogies are four-wheeled and are placed 21 feet centres. The wagon tare is 10 tons and the load is 16 tons. All rolling stock is fitted with the Jones central buffer and coupling.

	£
Locomotives cost about	2,000
First and Second Class composites	800
Third Class composites	500
Four-wheeled covered goods	87
Bogie covered goods	250

The ratio of carriages and wagons to engines being as 4 and 18 to 1. The total expenditure on rolling stock is $715,647, or $8,739 per mile of open line.

Working.

Fares and Rates.—The following Table shows the fares and rates charged for the carriage of passengers and goods. Passenger fares:—

First Class single	. . . .	8 cents per mile.
Second „	. . . .	5 „ „
Third „	. . . .	3 „ „

Return tickets for all classes are charged at one and a half single rates. First and second-class tickets are available for 7 days, third class for 3 days only. Season tickets are issued at an equivalent of two return journeys per week.

Goods are charged at the following rates:—

First Class goods	. . .	2 cents per pikul ($133\frac{1}{3}$ lbs.) per mile.
Second „	. . .	$1\frac{1}{2}$ „ „ „
Third „	. . .	1 „ „ „
Fourth „	. . .	$\frac{1}{2}$ „ „ „
Fifth „	. . .	$\frac{1}{4}$ „ „ „

Horses, &c., in horse-boxes 15 cents each per mile, minimum charge \$3 per animal. In cattle trucks holding four, 25 cents per truck per mile; five or more, 35 cents; minimum charge, \$1 per head. Calves, goats, sheep, &c., 1 cent per head per mile, minimum 50 cents per head. Carriage and carts on wheels 10 cents per mile, minimum \$3 per truck. The minimum charge for any single consignment of goods is 30 cents, except in case of fish, fruit, and meats, for which the minimum is 10 cents. First-class rates are charged on goods such as opium, silver, specie, poultry, and those that are dangerous or fragile; second class on goods such as beer, spirits, clothing, and furniture; third class on goods such as agricultural implements and hardware; fourth class on goods such as food stuffs; fifth class on goods such as bricks, cement, timber, etc. A rebate of 10 per cent. is allowed on consignments of fifth-class goods of 500 pikuls and over. A loading and unloading charge of 2 cents per pikul ($133\frac{1}{3}$ lbs.) is made at terminals.

Management and Staff.—The railway, being a single line one, is worked on the staff-and-ticket system, passenger trains running at a speed of 25 miles an hour, and goods at 20 miles an hour. The by-laws and regulations are framed on those of the metre-gauge lines of India. The administrative and executive branches of the service are in the hands of one officer (under the control of the Government), assisted by a staff of subordinates in charge

of traffic, ways and works, locomotive, telegraph, and stores sub-departments, which together employ over 1,200 men. Station-masters are invariably natives of India, and the clerical service are natives of China and India. Salaries vary between $100 per month, without overtime, for station-masters, clerks, and mechanics, to 30 cents per day for porters and others of the menial staff.

Coaching.—The coaching traffic is heavy and regular, and averages 250 passengers per train, 94 per cent. of whom are third class, 5 per cent. second, and 1 per cent. first, the average distance travelled per passenger being 13 miles. During the 10 years' working, the number of passengers carried per annum has increased from 130,000 to 1,353,700.

Goods Traffic.—The goods traffic consists principally of tin as an export, and rice and food stuffs as imports, the ratio of the bulk load of the latter to the former being as 4 to 1, the tonnage ratio being as 1½ to 1; a considerable proportion of the goods mileage is in consequence non-paying; with further development of the agricultural industries of the State this should cease to be so. The gross tonnage carried has increased during the last 10 years from 35,000 to 140,000.

Gross Earnings.—The gross earnings per mile open, per week, have increased from $136 in 1887 to $198 in 1896, the total gross earnings during that period being 4½ million dollars, and the ratio of passenger earnings to goods earnings being 1 to 2½.

Working Expenses.—The working expenses per train-mile for the different branches of the department are:—

Locomotive department	From	50	cents	to 60	cents.
Traffic "	"	60	"	" 70	"
Maintenance "	"	40	"	" 50	"
Telegraph "	"	1	"		
General management	"	11	"	" 13	"

the cost of each department per cent. of the total being:—

	Per cent.
Manager's department	4·4
Traffic "	32·1
Ways and Works department	34·5
Accountant's "	4·7
Locomotive "	22·3
Telegraph "	1·0
Stores "	1·0
	100·0

Ways and Works.—Since the opening of the first section of the railway in 1887, a considerable sum has been spent annually in enlarging stations to the traffic requirements, and in other improvements. This department houses all the railway employees at a rent of 7½ per cent. on the capital cost of the accommodation provided, the cost of maintaining these and other buildings being $80 per mile of open line. The permanent way originally laid of 46½-lb. rails is now being superseded by a rail weighing 60 lbs. per running yard; this has become necessary owing to the heavier type of engine now employed to meet the requirements of the increased and increasing traffic. The sleepers are of merbau (*afzelia palembanica*), one of the best hard woods of the country, and last between 5 years and 8 years after being laid. The maintenance expenses vary on different sections, that of the hill sections being greatest; this is due to the heavier rainfall of the hill country and the consequent damage to banks, cuttings, and bridges. A maintenance gang consists of ten coolies and one foreman to each 2 miles, supervised by a travelling timekeeper to each 10 miles, and an inspector to each 30 miles, the average cost of maintenance per mile being between $1,000 and $1,200 per annum.

Locomotive Department.—The total train-mileage run in 1887 was 29,348, in 1896, 230,589, the average run per engine during the latter year being 30,000 miles. The fuel used is wood, obtained locally. It is of a hard quality, and grows in the mud swamps on the coast; it is delivered in billets 2 feet 6 inches long, weighing 6 lbs., at a cost of $6½ per 1,000 pieces. Compared with coal at the current prices the cost per train-mile is 33 per cent. less, the average consumption per train-mile being 60 lbs. The running expenses per train-mile are as follows:—

	Per cent.
Fuel	6½
Oil, tallow, etc.	3½
Wages	5½

Repairs to the rolling stock are executed at the workshops, where carriages and wagons are also built. The cost of repairs is 11 cents per train-mile.

Conclusion.—A review of the progress made by the State since the construction and opening of the first section of the railway in 1887 is of interest, as showing the influence that the construction of these railways has had on the prosperity of the country. During the period under review, the State has spent on the construction and equipment of their lines $4,306,805, the whole of the expenditure having been met out of State revenue, the railway

contributing $2,600,000. The gross revenue of the State during this period has increased from $1,154,000 to $3,756,000, while the increase in the value of the exports and imports, as well as the increase of population, has been very great, a result which must be highly gratifying to those responsible for the conception and achievement of a policy which resulted in the construction of the railway, and one which illustrates the influence played by railways in the development of sparsely populated countries.

The construction of these lines was carried out under the direction, as Consulting Engineers, of Messrs. Gregory and Eyles, M. Inst. C.E., Mr. A. J. Watkins, M. Inst. C.E., being the Chief Resident Engineer. To the last mentioned the Author is indebted for placing at his disposal the means of obtaining most of the information contained in these notes.

The Paper is accompanied by four tracings, from which Plate 6 has been prepared.

(*Paper No. 3160.*)

"The North-East Dundas Tramway, Tasmania."

By WILLIAM PRIOR HALES, M. Inst. C.E.

THE Western District of Tasmania possesses numerous mineral deposits, principally copper pyrites, often carrying silver and gold, and galena carrying silver. To develop the district in the neighbourhood of Mounts Zeehan and Dundas the Tasmanian Government constructed a railway of 3-foot 6-inch gauge, 29 miles in length, from the port of Strahan on Macquarie Harbour to the town of Zeehan, Fig. 1, Plate 7. This line was opened in 1892 and cost £8,058 per mile, including rolling stock and wharf at Strahan.

In 1895 it was decided to extend railway communication from Zeehan in a north-easterly direction to the Ring River valley at the foot of Mount Read, to tap the numerous mineral deposits known to exist, and, in a few cases, partly opened out. The existing means of communication were pack tracks, 4 feet wide, and the cost of packing goods and minerals was about 1*d.* per lb. The country to be traversed was very rugged, and it was considered that the standard gauge, 3 feet 6 inches, with a minimum radius of five chains on curves, would cost over £10,000 per mile. It was decided for numerous reasons to construct a tramway of 2-foot gauge with curves of not less than 99 feet radius.

Survey.—The survey was begun in November 1895. Zeehan, the starting point, is 533 feet above sea-level. Between this and the Ring River valley there is a long spur, running in a north-westerly direction from Mount Dundas, with only one practicable saddle, 1,520 feet above sea-level. The preliminary survey on the Zeehan side was complicated by another long spur from Mount Dundas with several saddles 1,000 feet to 1,300 feet above sea-level. From the summit, known as the Confidence saddle, an accurate preliminary traverse and levels were run each way simultaneously, adhering as closely as possible to the gradients determined on. This was

regulated by the leveller, who reduced the principal surface and formation levels in the field. Occasionally the transit man also could indicate the direction of traverse by setting to the vertical angle of the gradient. The maximum gradient against outward loads was fixed at 1 in 25, and against inward mineral loads at 1 in 30 (Fig. 2, Plate 7). The traverse was plotted by latitude and departure to a scale of 1 inch to 1 chain, reduced levels being figured on, and the angles of cross slopes indicated about every 2 chains. The permanent line was then laid down on the plan, contour lines 5 feet or 10 feet above and below gradient being in many places first laid down as a guide to safe and economical location. The cross slopes being in many places 30° and even 45° would not hold a bank, and in most cases the line was located in the solid. In a few instances small retaining walls of dry stone were adopted.

To 5¼ miles the line traverses easy country, attains a height of 734 feet above sea-level, and has thirteen curves with a minimum radius of 5 chains. From 5¼ miles to the terminus at Deep Lead, 17 miles 70 chains, the line is almost a continuous succession of reverse and compound curves, the average number being thirty per mile. A length of at least 40 links, or 26·4 feet, was left in all cases between reverse curves. Except in difficult cases the tangent points and intersections were fixed by careful measurements on the plan, and the curves were ranged by offsets from the tangent lines. This method was found to be expeditious and fairly satisfactory. Four miles of the line are on curves of 1½ chain radius, and nearly 2 miles are on curves of 2 chains radius. The survey cost £103 per mile.

Clearing and Timber.—From 3 miles to the terminus the country is densely timbered, principally with myrtle (*Fagus cunninghamii*), peppermint (*Eucalyptus amygdalina*), King William pine (*Athrotaxis selaginoides*), celery top pine (*Dacrydium franklinii*), and blackwood (*Acacia melanoxylon*). Other small and unimportant trees are sassafras (*Atherosperma moschatum*), cheesewood (*Eriostemon squameus*), horizontal (*Anodopetalum biglandulosum*), and leatherwood (*Eucryphia billardieri*). Only three of these were durable enough for construction, viz., peppermint for all purposes, celery top pine for piles and log culverts, and leatherwood also for log culverts. The timbers used in bridges, box culverts and sleepers, were stringy bark, blue gum, and a little peppermint, almost entirely from the extensive forests of the Huon River district in Southern Tasmania. The heart timber of the Eucalypti for about 3 inches or 4 inches from the centre, warps and decays

rapidly when sawn, and is therefore rejected. For this reason, and for facility of renewal, beams of any size are used in pairs, as shown in Figs. 4, Plate 7. The sap is generally 1 inch to 2 inches thick, and the timber nearest the sap is considered the best.

The line was cleared in the first instance to a width of 30 feet, and the clearing is being gradually widened by timber-getters at no cost to the line, which makes a profit on the freight.

Earthworks.—The formation width of cuttings and embankments is 10 feet, and the batters of cuttings were made as steep as possible, frequently ¼ to 1. The material was mostly slate, clay slate, trap rock and sandstone. Most of this work was done by day labour, and, to ensure economy, each ganger's work was measured, and the cost of labour and explosives was charged against it. Piecework men were found in all tools, plant and material, except shovels and explosives. In spite of the numerous curves to avoid heavy works, the earthworks totalled 247,769 cubic yards, or an average of about 14,000 cubic yards per mile. The average cost was 1*s.* 11*d.* per cubic yard. Although there is a heavy rainfall, very little side ditching was required owing to the solidity of the rock and the absorbent nature of the overlying surface soil. Light wagon roads were used on the larger cuttings; the rails were 14 lbs. per yard, on sleepers of split timber, and iron tip-trucks of ¾ cubic yard capacity were employed. The rails and trucks had to be hauled along pack tracks and then carried by men to cuttings. On curves, a cant was put on the formation.

Culverts.—The larger culverts are built of logs, 15 inches to 18 inches in diameter, roughly squared where bedded on one another. Their life is at least thirty years. They vary in size between 2 feet by 1 foot and 6 feet by 3 feet (double) clear opening. Smaller ones between 12 inches by 9 inches and 2 feet by 2 feet are of sawn timber. Wherever possible, in gullies having a steep fall, the culverts are built as near to formation level as possible and a contoured inlet is cut. In one case a gully 30 feet deep is thus dealt with, and a box culvert, 12 feet long, with a 12-inch by 9-inch opening, takes the water. In another case a flume 60 feet in length, conducts the water from what was originally a waterfall 30 feet high to a box culvert 2 feet by 2 feet at formation level. The small spaces left on the upper side of the bank are amply provided for by drains filled with brushwood.

Bridges.—Nine bridges and one overbridge were built. The spans adopted were 11 feet, 13 feet, 15 feet, 25 feet understrutted, and 30 feet understrutted. They are all of timber, the piles, except

those of Montezuma bridge, being of round timber, 18 inches in diameter. In one case piles were shod and driven. In all others the piles are tenoned to sills bedded in the rock or are footed and bedded in Portland cement concrete. Concrete was composed of 1 part of cement, 3 parts sand or tailings, and 5 parts broken stone, larger stones being built in where possible. The concrete required much longer to set when tailings were used. The latter were largely composed of carbonate of iron and were obtained from a galena dressing mill. The superstructures are of sawn timber and have two pairs of beams for facility of renewal, 14 inches by 7 inches for 11-foot spans, and 15 inches by 7 inches for all other spans. The general character of the bridges is shown in the drawing of No. 6 bridge, Fig. 3, Plate 7, which is 60 yards from the foot of the Montezuma falls, 340 feet high. The bridge being on a curve of 2 chains radius precluded the adoption of longer spans than 25 feet.

Permanent Way.—The rails are of steel, Vignoles section, 24 feet in length, and, excepting about 1 mile of 40 lbs. section, weigh 46 lbs. per yard. The fishplates are of bar section, 14 inches in length, with four bolt holes, weighing 8½ lbs. per pair; the fishbolts are ¾ inch in diameter. The dog-spikes are 4 inches by $\frac{9}{16}$-inch square, manufactured in the colony. All rails, fishplates and bolts are second-hand, and were taken from the main line from Hobart to Launceston, 3 feet 6 inches gauge, which is being relaid with a heavier rail. The rails were bent to the curves as accurately as possible by a hand press. As the press could not curve the extreme ends this was done by a jim-crow after the rails were fished. The joint sleepers are 2 feet centres, and the joints are "suspended" and square. To 5¼ miles the curves are canted for a speed of 20 miles per hour, and beyond that point for a speed of 12 miles per hour. The switches are 7 feet long, angle 1 in 21, and are planed to fit the stock rails in the usual way; crossings angle 1 in 6, and are 46-lb. steel rails, having a turnout curve of 135 feet radius. The sleepers are of stringy bark and blue-gum, 5 feet by 8 inches by 4 inches, 1,980 per mile, machine adzed and bored; the inclination of rail seat is 1 in 26. They cost 9½*d.* each delivered at Strahan. Ballast was composed of a kind of breccia; also about 4 miles were ballasted with tailings from a galena dressing mill. The depth under the sleepers is 4 inches and the total depth 8 inches, the average width being 6 feet 9 inches. The estimated quantity was 800 cubic yards per mile; the actual quantity as measured in trucks was nearly 1,000 cubic yards per mile.

Rolling Stock.—The first engine acquired was by Krauss of Munich, with four coupled wheels 2 feet in diameter, and cylinders 6¼ inches in diameter by 11 inches stroke, weighing in steam 6½ tons. She proved extremely useful and hauled all material, including ballast, for the first 11 miles of construction. The type of engine adopted for permanent working (Fig. 5, Plate 7) was built by Messrs. Sharp, Stewart & Co. of Glasgow, and has the following general dimensions, etc.:—

Cylinders	12 inches in diameter, by 16 inches stroke.
Four coupled wheels	2 feet 6 inches in diameter.
Trailing bogie wheels	1 foot 9 inches in diameter.
Fixed wheel base	5 feet 6 inches.
Total " "	10 feet 3 inches.
Weight in steam	19¾ tons.
Water tanks (side)	550 gallons.
Fuel capacity	60 cubic feet.
Heating surface, firebox	42 square feet.
" " tubes	340 " "
	382
Grate area	9¼ square feet.
Boiler pressure	140 lbs. per square inch.
Tractive force with 100 lbs. per square inch mean cylinder pressure	7,680 lbs.

The engine is fitted with vacuum brake gear, and hauls four loaded eight-wheel trucks, weighing a little over 50 tons, against the maximum resistance of a 1 in 27 gradient, combined with curves of 1½ chains radius. Two of these engines are now in use.

The other rolling stock was built in the Launceston Railway workshops, and comprised twenty-five eight-wheel low-side trucks (Fig. 6, Plate 7), tare 3 tons 1 cwt. 1 qr., load 10 tons; six eight-wheel flat trucks, tare 2 tons 18 cwt. 1 qr., load 10 tons; two four-wheel bolster trucks, for carrying long timber, tare 1 ton 19 cwt., load 5 tons (Fig. 7, Plate 7); and four passenger cars, each with six cross-seats with reversible backs, to carry eighteen passengers, also a locker for mails and parcels. All trucks and cars have cast-steel wheels 21 inches in diameter, and are fitted with automatic vacuum brakes. The trucks have side levers and the cars have hand-screw brakes. The vacuum brake can be worked from the engine or from the passenger cars, which act as brake vans. When this brake was introduced, one effect was to accelerate the journey speed by about 10 minutes, owing to more even running on down gradients.

Stations and Equipment.—Besides the termini at Zeehan and Deep Lead, there are five stations, and provision is made for seven more stations when required. The buildings are of the simplest and most inexpensive kind, with no platforms, a 20-foot turntable at each terminus, and at Zeehan a 20-ton weighbridge. At Zeehan the arrangements for transfer of ore, timber, etc., to and from the 3-foot 6-inch gauge railway consist simply of a railway siding and a tramway siding laid as close together as possible, the tramway rails being 8 inches higher so that the truck-floors on both gauges are at the same level. For general merchandise a 2-foot gauge siding was laid along the cart entrance side of the goods shed; its floor is therefore between the two gauges. The tramway is connected with the Zeehan street tramway, which runs through the town and ramifies to seven galena mines. These mines draw large supplies of firewood and mining timber from the forest through which the North-East Dundas Tramway runs. This street tramway has similar arrangements for the transfer of traffic, which have answered satisfactorily for some years. It transfers to the Strahan Railway about 20,000 tons per annum of galena (silver lead ore), in 1-cwt. bags, at a cost of about $1\frac{1}{2}d.$ per ton.

Working.—The traffic is worked by the staff and ticket system, and the staff stations are connected by telephone. The maximum journey speed is limited to 12 miles per hour on the first $5\frac{1}{4}$ miles, and to 8 miles per hour on the remainder. The North-East Dundas Tramway is at present returning a profit above working expenses of 3·3 per cent. on the capital expenditure.

A summary of the cost of the line is shown in the following Table:—

	£.	s.	d.
Survey	1,823	8	11
Clearing	1,588	2	4
Earthwork	23,983	9	7
Bridges and culverts	3,440	16	5
Permanent way	9,367	17	3
Ballasting	3,807	7	2
Buildings	568	17	9
Equipment	568	16	4
Rolling stock	4,166	19	11
Staff	1,060	1	2
	£50,375	16	10

Cost per mile, £2,823.

The work was carried out by the railway department, without the intervention of a contractor, under the direction of Mr. F. Back, Assoc. M. Inst. C.E., general manager, and Mr. J. M. McCormick,

M. Inst. C.E., engineer of existing lines, the Author being resident engineer. As soon as the plans for the first 2 miles or 3 miles were completed, construction was begun at the Zeehan end, on the 17th January, 1896. The maximum rate for ordinary labour was fixed at 7*s.* per day, and was afterwards raised to 8*s.* per day, about 3 months before the completion of the line in February, 1898.

As far as possible the work was let by the piece to butty gangs, but the greater part was performed by day labour.

The Paper is accompanied by seven drawings, from which Plate 7 has been prepared.

(*Paper No. 3170.*)

"Transition Curves for Railways."

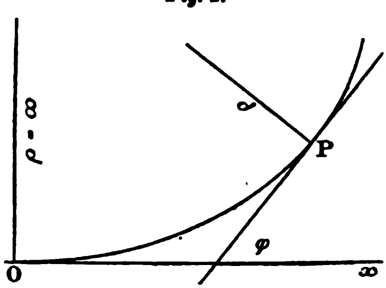
By James Glover, M.A., Assoc. M. Inst. C.E.

Railway centre-line alignment, as traced on a horizontal plane, usually consists of portions of circles and straight lines tangential to them. If the circles are of large radius the initial change of direction on entering the curve is comparatively gradual and the motion is easy and safe; but if the circles are of small radius the change of direction is abrupt, and the motion is oscillatory, jerky and unpleasant, and at high speeds dangerous. In addition, the super-elevation of the outer rail to correspond to the maximum speed on the circular portion is improperly commenced on the straight portion of the line where no super-elevation is required. By the insertion of a properly-designed transition curve between the straight line and the circular arc these inconveniences and difficulties are obviated, and comfort and safety at the maximum speeds are attained. The Author proposes to treat of the theory of the transition curve (Part I), and then to apply it to railway curves (Part II).

Part I.

(*a*) *To find the Equation of a Suitable Transition Curve.*—From the foregoing remarks it is evident that a perfect transition curve must fulfil the following condition: The radius of curvature at any point must be inversely proportional to the length of curve between the point and that end of the curve at which it has its maximum value. This suggests that the intrinsic form of equation for the initial analysis will be simplest.

Fig. 1.



In *Fig. 1* let O be the origin on the reference line O x and

P any point on the curve. Let λ be the length of the curve O P, and ϕ the angle which the tangent at P makes with the reference line O x. Let O x be tangential to the curve at O.

Then $$\lambda = f(\phi) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

is the intrinsic equation of the curve;

Now ρ (the radius of curvature at any point P) $= \dfrac{d\lambda}{d\phi}$

but by hypothesis $\rho = \dfrac{\kappa}{\lambda}$, where κ is a constant . (2)

$$\therefore \frac{d\lambda}{d\phi} = \frac{\kappa}{\lambda} \text{ and } \lambda = \sqrt{2\kappa\phi} + \text{constant} \quad . \quad . \quad (3)$$

as $\lambda = 0$ when $\phi = 0$ the constant is zero.

$$\therefore \lambda = \sqrt{2\kappa\phi}, \text{ but if } \lambda = l \text{ when } \phi = a, \kappa = \frac{l^2}{2a},$$

whence it follows that—

$$\lambda = \frac{l}{\sqrt{a}}\sqrt{\phi}, \text{ and if } \rho = r \text{ when } \lambda = l, \text{ then } \kappa = rl \text{ and } r = \frac{l}{2a} \quad (4)$$

and $$\lambda = 2r\sqrt{a}\sqrt{\phi} \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

also $$\lambda = \sqrt{2rl}\sqrt{\phi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

and $$\rho = \frac{rl}{\lambda} = \frac{l^2}{2a\lambda} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Equations (4), (5) and (6) are different forms representing the same transition curve,

$$\lambda = m\sqrt{\phi} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

which perfectly fulfils the necessary condition.

At this stage it is convenient to refer the curve to Cartesian co-ordinates.

Projecting an element of the curve on the rectangular axes of x and y—

$$dx = d\lambda \cos\phi$$
$$= \frac{m}{2}\frac{\cos\phi}{\sqrt{\phi}}\,d\phi.$$

Expanding and integrating—

$$x = m\sqrt{\phi}\left(1 - \frac{\phi^2}{5\lfloor 2} + \frac{\phi^4}{9\lfloor 4} - \frac{\phi^6}{13\lfloor 6} + \ldots - \ldots\right) \quad (9)$$

also
$$dy = d\lambda \sin\phi$$
$$= \frac{m}{2}\frac{\sin\phi}{\sqrt{\phi}}\,d\phi.$$

$$\therefore y = \frac{m}{3}\phi^{\frac{3}{2}}\left(1 - \frac{3\phi^2}{7\,\lfloor 3} + \frac{3\phi^4}{11\,\lfloor 5} - \frac{3\phi^6}{15\,\lfloor 7} + \cdot\cdot - \cdot\cdot\right) \quad (10)$$

Eliminating ϕ between (9) and (10) the Cartesian equation of the curve is arrived at. If ϕ be small we may neglect ϕ^2 and higher powers.

$$\left.\begin{aligned}\therefore x &= m\sqrt{\phi}\\ \text{and}\quad y &= \frac{m}{3}\phi^{\frac{3}{2}}\end{aligned}\right\}\text{approximately.}$$

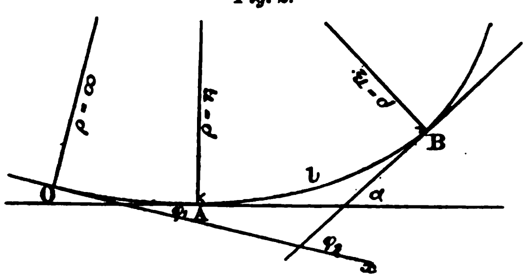
$$\therefore y = \frac{x^3}{3m^2}; \text{ a cubic parabola} \quad . \quad . \quad . \quad (11)$$

If (a, b) be any given point on this curve—

$$y = \frac{b\,x^3}{a^3}.$$

(β) In the transition curve $\lambda = m\sqrt{\phi}$, to find a relation connecting two radii of curvature r_1, r_2, the length of the curve l between them, and the angle α included by them.

Fig. 2.



Let O be the origin of the curve $\lambda = m\sqrt{\phi}$, at which the radius of curvature is infinitely great, r_1 and r_2 the radii of curvature at A and B, and let l be the length of the curve A B; the angle between the tangents at A and B = the angle included by the radii r_1 and r_2 and $= \alpha$.

Then (*Fig. 2*)
$$O A = \lambda_1 = m\sqrt{\phi_1}$$
$$O B = \lambda_2 = m\sqrt{\phi_2}$$
$$\lambda_2 - \lambda_1 = l = m(\sqrt{\phi_2} - \sqrt{\phi_1}).$$

Again
$$\frac{d\lambda}{d\phi} = \frac{m}{2\sqrt{\phi}} = \rho$$

$$\therefore r_1 = \frac{m}{2\sqrt{\phi_1}}\,;\; r_2 = \frac{m}{2\sqrt{\phi_2}}$$

$$\therefore \sqrt{\phi_2} - \sqrt{\phi_1} = \frac{m}{2}\,\frac{r_1 - r_2}{r_1\, r_2}$$

and
$$\sqrt{\phi_2} + \sqrt{\phi_1} = \frac{m}{2}\,\frac{r_1 + r_2}{r_1\, r_2}$$

$$\therefore \phi_2 - \phi_1 = a = \frac{m^2}{4}\,\frac{r_1^{\,2} - r_2^{\,2}}{r_1^{\,2}\, r_2^{\,2}}\,;$$

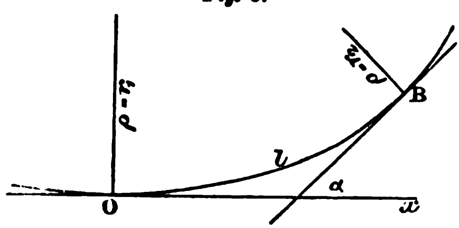
it follows therefore that $l = \dfrac{m^2}{2}\,\dfrac{r_1 - r_2}{r_1\, r_2}$

and
$$\frac{l}{a} = \frac{2\, r_1\, r_2}{r_1 + r_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

an exact relation between the required elements.

(γ) The previous equations have referred the curve to the point O at which the radius of curvature is infinitely great. If

Fig. 3.



the radius of curvature at O $= r_1$, and at B $= r_2$, and the length of curve O B $= l$, then the equation will be of the form—

$$\lambda + \lambda_1 = \text{M}\sqrt{\phi + \phi_1} \quad . \quad . \quad . \quad . \quad (13)$$

where λ_1 and ϕ_1 refer to the point on the curve at which $\rho = \infty$;

hence
$$\frac{d\lambda}{d\phi} = \frac{\text{M}^2}{2(\lambda + \lambda_1)} = \rho$$

and $\rho = r_1$ when $\lambda = 0$, $\lambda = l$ when $\phi = a$,

and $\rho = r_2$ when $\lambda = l$,

$$\left.\begin{aligned} \therefore r_1 &= \frac{\text{M}^2}{2\lambda_1} \\ \text{and} \qquad r_2 &= \frac{\text{M}^2}{2(\lambda_1 + l)} \\ \text{and from (13)} \qquad (\lambda_1 + l) &= \text{M}\sqrt{\phi_1 + a} \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (14)$$

From (14) it follows that—

$$\lambda_1 = \frac{r_2\, l}{r_1 - r_2};\ \phi_1 = \frac{r_1\, l}{2\, r_2\,(r_1 - r_2)} - a$$

$$M^2 = \frac{2\, r_1\, r_2\, l}{r_1 - r_2}.$$

Substituting these values in (13) the equation obtained is—

$$\left.\begin{aligned} \left(\lambda + \frac{r_2\, l}{r_1 - r_2}\right) & \sqrt{\frac{2\, r_1\, r_2\, l}{r_1 - r_2}}\left(\phi + \frac{l\, r_1}{2\, r_2\,(r_1 - r_2)} - a\right)^{\frac{1}{2}} \\ & = \sqrt{\frac{2\, r_1\, r_2\, l}{r_1 - r_2}}\left(\phi + \frac{l\, r_2}{2\, r_1\,(r_1 - r_2)}\right)^{\frac{1}{2}} \end{aligned}\right\} \quad (15)$$

the intrinsic equation to the curve referred to a point on the curve as origin at which the radius of curvature is r_1, and in terms of r_1 and r_2, and the length l of the curve, and the angle between r_1 and r_2, *Fig. 3*.

Putting $r_1 = \infty$ and $l = 2\, r_2\, a$ in (15) the equation reduces to the forms (4) to (6).

Referring curve (13) to Cartesian co-ordinates (taking the tangent at O for axis of x and the normal at O for axis of y and the radius of curvature at O $= r_1$) and projecting an element of the curve on to the axis of x (equation (13)), as before—

$$d\,x = \frac{M}{2}\,\frac{\cos\phi}{\sqrt{\phi + \phi_1}}\, d\,\phi, \text{ and similarly } d\,y = \frac{M}{2}\,\frac{\sin\phi}{\sqrt{\phi + \phi_1}}\, d\,\phi \quad (16)$$

If ϕ be small—

$$x = \frac{M}{2}\int \frac{d\,\phi}{\sqrt{\phi + \phi_1}} = M\sqrt{\phi + \phi_1} + \text{constant.}$$

Now $x = 0$ when $\phi = 0$—

$$\therefore \text{constant} = -\sqrt{\phi_1}\cdot M;$$

$$\therefore x = M\sqrt{\phi + \phi_1} - M\sqrt{\phi_1}.$$

Again—

$$y = \frac{M}{2}\int \frac{\phi}{\sqrt{\phi + \phi_1}}\, d\,\phi = \frac{M}{2} \times 2\left(\frac{(\phi + \phi_1)^{\frac{3}{2}}}{3} - \phi_1\sqrt{\phi + \phi_1}\right) + \text{constant.}$$

Now when $\phi = 0$, $y = 0$,

$$\text{and the constant} = \left(\phi_1^{\frac{3}{2}} - \frac{\phi_1^{\frac{3}{2}}}{3}\right) M = \frac{2\, M}{3}\,\phi_1^{\frac{3}{2}};$$

$$\therefore y = M\left(\frac{(\phi + \phi_1)^{\frac{3}{2}}}{3} - \phi_1\,(\phi + \phi_1)^{\frac{1}{2}}\right) + \frac{2\, M}{3}\,\phi_1^{\frac{3}{2}};$$

substituting from above $\sqrt{\phi + \phi_1} = \dfrac{x + M\sqrt{\phi_1}}{M}$ to eliminate ϕ it follows that—

$$y = M\left(\frac{(x + M\sqrt{\phi_1})^3}{3M^3} - \phi_1\frac{(x + M\sqrt{\phi_1})}{M}\right) + \frac{2M}{3}\phi_1^{\frac{3}{2}}$$

$$= \frac{x^3}{3M^2} + \frac{x^2}{M}\sqrt{\phi_1},$$

and writing M and ϕ_1 in terms of l, r_1 and r_2 from (14)—

$$y = \frac{x^3(r_1 - r_2)}{6lr_1r_2} + \frac{x^2}{2r_1}, \quad . \quad . \quad . \quad . \quad (17)$$

the Cartesian equation required, is arrived at.

Putting $r_1 = \infty$ in (17), equation (11) is obtained.

The assumption in (15) that ϕ is small gives sufficiently accurate results for railway curves and simplifies the integration; if the particular problem necessitates the retention of ϕ^2 the functions of ϕ in (16) may be expanded in series by Maclaurin's theorem and then integrated.

(δ) *General Equations of Transition Curves:—*

Let
$$\lambda = m\phi^n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (i)$$

be the intrinsic equation of the transition curve, *Fig. 1.* Then—

$$\frac{d\lambda}{d\phi} = mn\phi^{n-1} = \rho \quad . \quad . \quad . \quad . \quad . \quad . \quad (ii)$$

If l and a be the co-ordinates of a point P, at which the radius of curvature $= r$—

$$l = ma^n$$

and
$$r = mna^{n-1}$$

$$\therefore n = \frac{ra}{l},$$

and
$$\lambda = l\left(\frac{\phi}{a}\right)^{\frac{ra}{l}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (iii)$$

is the complete equation of the curve referred to the tangent at the origin of the curve as reference line.

Now ra is the length of the circular curve displaced by the transition curve (Part II (a)) and l is the length of the transition curve.

By this equation a transition curve of given length can be found to fit any two tangents, and if $r\,a = \frac{l}{2}$ it will be a true transition curve, fulfilling the condition $\rho \propto \frac{1}{\lambda}$. However, if $r\,a$ and l are fixed quantities and $r\,a < l$, the resulting equation will be the best form and nearest approach to $\lambda = m\sqrt{\phi}$ the circumstances permit.

From (i) equations (5) and (6) may at once be obtained. Thus—

$$\frac{d\lambda}{d\phi} = \rho = m\,n\,\phi^{n-1}$$

$$= m\,n\left(\frac{\lambda}{m}\right)^{\frac{n-1}{n}} = \mathrm{K}\,\lambda^{\frac{n-1}{n}}.$$

But for the transition curve (8) the condition $\rho = \frac{\kappa}{\lambda}$ must hold good.

$$\therefore \lambda^{-1} = \lambda^{\frac{n-1}{n}}$$

$$\therefore n = \tfrac{1}{2}$$

and

$$\therefore \lambda = m\,\phi^{\frac{1}{2}}$$

is the intrinsic equation of the curve for which $\rho \propto \frac{1}{\lambda}$, and this agrees with ($a$), Part I.

Example—

Let $\frac{r\,a}{l} = \tfrac{1}{3}$,

then (iii) becomes $\lambda = l\left(\frac{\phi}{a}\right)^{\frac{1}{3}}$

$$\rho = \frac{l^3}{3\,a}\cdot\frac{1}{\lambda^2} \text{ or } \rho \propto \frac{1}{\lambda^2}.$$

Changing to Cartesian co-ordinates (assuming ϕ small) it is found that—

$$y = \int \sin\phi\,d\lambda = \int \frac{m}{3}\frac{\sin\phi}{\phi^{\frac{2}{3}}}\,d\phi$$

$$= \frac{m}{4}\,\phi^{\frac{4}{3}} \text{ nearly,}$$

and similarly $x = m\,\phi^{\frac{1}{3}}$,,

$\therefore y = \frac{x^4}{4\,m^3} = \frac{a}{4\,l^3}\,x^4 = \frac{x^4}{12\,r\,l^2} = \frac{b}{a^4}\,x^4$ (a, b being the co-ordinates of

a given point), the Cartesian equation required. And similarly corresponding equations may be obtained for any other value of $\frac{r\,a}{l} < 1$; of course, this limit is imposed by the circular curve.

(ϵ) It may be interesting to show that the curve $\lambda = m\sqrt{\phi}$ is the most suitable transition curve.

Let e be the super-elevation of the outside rail, at the point (λ, ϕ) on the curve, required to counteract the overturning tendency of the centrifugal force due to the maximum velocity, then $e = \frac{K}{\rho}$, where K is a constant involving the maximum velocity (Rankine, "Civil Engineering," p. 649), and e will be zero at the origin of the curve when $\rho = \infty$, and will attain its maximum value E at (l, a) where the curve joins the circle, radius r.

Let $\lambda = m\,\phi^n$ be the equation of the transition curve, then

$$\rho = m\,n\,\phi^{n-1} = m\,n\left(\frac{\lambda}{m}\right)^{\frac{n-1}{n}},$$

or

$$\rho \propto \lambda^{\frac{n-1}{n}};$$

but

$$e \propto \frac{1}{\rho} \propto \lambda^{\frac{1-n}{n}},$$

or

$$e = N\,\lambda^{\frac{1-n}{n}} \text{ where N is a constant.}$$

If e and λ be considered as running co-ordinates referred to rectangular axes, this will be the equation of the gradient of approach along the exterior rail (as traced on a vertical plane) from the level zero to E.

It is evident that the simplest form of gradient for practical purposes is a straight line; for this equation to represent a straight line the condition is that $\frac{1-n}{n} = 1$, or $n = \frac{1}{2}$, and substituting this in the general equation, $\lambda = m\sqrt{\phi}$ is arrived at as the equation of the most suitable transition curve, and it is also the simplest, because $\rho \propto \frac{1}{\lambda}$. The Author has called this a true or perfect transition curve.

Part II.

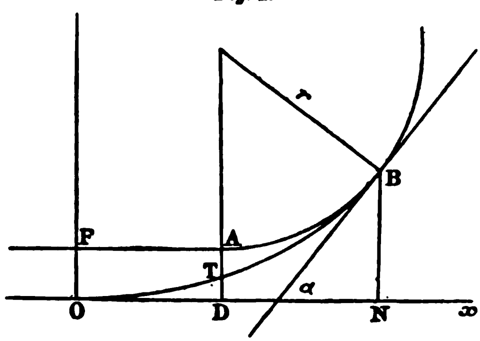
(*a*) The application of transition curve $\lambda = m\sqrt{\phi}$ to railway curves.

Let A B be a circular curve, radius r; and let A F be the tangent at A. It is required to connect the circle at B with a tangent parallel to A F by means of a transition curve, such that the radius of curvature at B = r, and at O, the point on the parallel tangent, $\rho = \infty$, the angle the tangent at B makes with A F or O D = a. Let l = the length of the transition curve O B.

Then $$\lambda = m\sqrt{\phi} = 2r\sqrt{a}\sqrt{\phi} \quad . \quad . \quad . \quad (18)$$

is the intrinsic equation of O B (Eq. 5). Now the portion of

Fig. 4.



circle A B displaced by the transition curve = ra and substituting a for ϕ in (18) it follows that—

$$\lambda = l = 2r\sqrt{a}\sqrt{\phi} = 2ra.$$

Therefore $$l = 2\,\text{A B} \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

or the transition curve is exactly twice the length of the displaced circular curve.

Again from (11) and (6)

$$y = \frac{x^3}{6rl}$$

and when ϕ is small the abscissa of a point and the distance along the curve may be considered equal.

$$\therefore \text{ when } x = \frac{l}{2}, \text{ T D} = y = \frac{l^2}{48r}.$$

$$\left.\begin{array}{l}\text{And } BN = AD + \dfrac{AB^2}{2\,r} = s\,(\text{the shift}) + \dfrac{l^2}{8\,r} \text{ by the circle.} \\[2ex] \text{But } BN = \dfrac{l^3}{6\,r\,l} = \dfrac{l^2}{6\,r} \text{ by the transition curve,}\end{array}\right\}(20)$$

$$\therefore s = \frac{l^2}{24\,r}.$$

And $TD = \dfrac{l^2}{48\,r}$; $\therefore$ the transition curve bisects the shift s in T.

Again $$BN - AD = \frac{l^2}{8\,r} = 3\,s \quad . \quad . \quad . \quad . \quad . \quad (21)$$

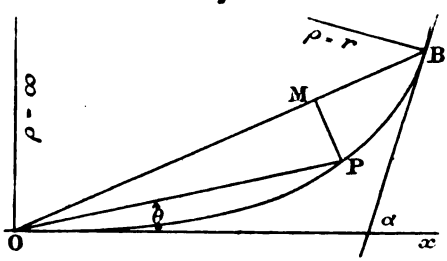
Let any chord O P make an angle θ with Ox, then $\tan\theta = \dfrac{y}{x}$, but for any point on the transition curve $y = m\,x^3$

$$\tan\phi = \frac{d\,y}{d\,x} = \frac{3\,y}{x}$$

$$\therefore \tan\theta = \tfrac{1}{3}\tan\phi;\ \therefore \text{ if } \phi \text{ is small } \theta = \frac{\phi}{3}. \quad . \quad (22)$$

This also follows immediately from (9) and (10).

Fig. 5.



Again $$\lambda = m\sqrt{\phi},\ \therefore \phi = \frac{\lambda^2}{m^2} = a\left(\frac{\lambda}{l}\right)^2.$$

And $$\theta = \frac{\phi}{3} = \frac{a}{3}\left(\frac{\lambda}{l}\right)^2 \text{ when } a \text{ is small and } \lambda < \text{ or } = l \quad (23)$$

(for any point P, *Fig. 5*).

If $z = PM =$ the ordinate from P, a point on the curve $\lambda = m\sqrt{\phi}$ to the chord O B through the origin—

$$OP = \lambda$$

$$\theta = POx = \frac{a}{3}\left(\frac{\lambda}{l}\right)^2,$$

and $$PM = OP \times \angle POM$$
$$= z = OP \times \angle\,(BOx - POx).$$

$$\therefore z = \frac{\lambda a}{3}\left(1 - \left(\frac{\lambda}{l}\right)^2\right) \quad . \quad . \quad . \quad . \quad (24)$$

By this equation the curve can be set out from the chord.

It follows directly that z is a maximum when $\lambda = \frac{l}{\sqrt{3}}$, and for this value $z = \frac{2\,l\,a}{9\sqrt{3}}$.

The following are the collected results for $\lambda = m\sqrt{\phi}$, *Figs.* 4 and 5—

Formulas (A).

$$\lambda = m\sqrt{\phi} = 2\,r\sqrt{a}\sqrt{\phi} = \sqrt{2\,r\,l\,\phi}.$$

$$\rho = \frac{m}{2\sqrt{\phi}} = \frac{r\sqrt{a}}{\sqrt{\phi}} = \sqrt{\frac{r\,l}{2\,\phi}} = \frac{r\,l}{\lambda}.$$

$l = 2\,r\,a$; $l = 2f$, where f = length of displaced circular arc.

$$s = \frac{l^2}{24\,r}.$$

$$y = \frac{m}{3}\phi^{\frac{3}{2}}\left(1 - \frac{3\,\phi^2}{7\,\underline{|3}} + \ldots\right) = \frac{m}{3}\phi^{\frac{3}{2}} \text{ nearly.}$$

$$x = m\sqrt{\phi}\left(1 - \frac{\phi^2}{5\,\underline{|2}} + \ldots\right) = m\sqrt{\phi} \text{ nearly.}$$

$$y = \frac{x^3}{3\,m^2} = \frac{bx^3}{a^3}; \quad \phi = \frac{3\,y}{x}; \quad a = \frac{3\,b}{a}; \quad \rho = \frac{a^3}{6\,x\,b}.$$

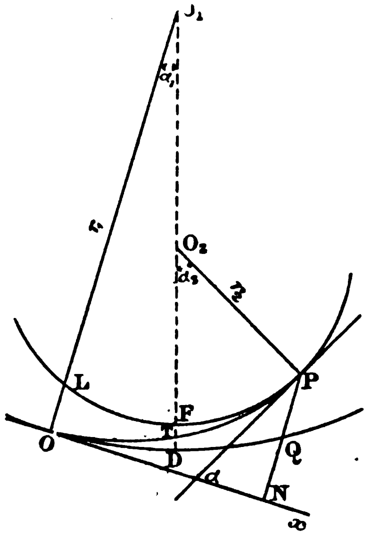
$$\tan\theta = \frac{\phi}{3} \text{ or } \theta = \frac{\phi}{3}, \text{ when } \phi^2 \text{ neglected} = \frac{a}{3}\left(\frac{\lambda}{l}\right)^2.$$

$$z = \frac{\lambda a}{3}\left(1 - \left(\frac{\lambda}{l}\right)^2\right) = \text{ordinate from curve to chord.}$$

In practice l is usually taken any convenient length from $l = 25.\mathrm{E}$ to $l = 50.\mathrm{E}$, or greater, where l is in feet and E is the super-elevation of the outer rail of the circular curve in inches required to suit the maximum speed. The super-elevation is nothing at O and gradually increases along the transition curve to its maximum E at B. It is easily seen that for the insertion of a transition curve either the original tangent to the circle may be displaced parallel to itself by the amount of shift (s), or the circular curve may be displaced by the same amount.

(β) To lay out a transition curve connecting two non-intersecting circular curves:—

Fig 6.



Let P L and O Q, *Fig. 6*, be the two circular curves of radii r_2 and r_1, with centres at O_2 and O_1. Produce $O_1 O_2$ to cut the circles in F and D, then F D = s = the shift or shortest distance between the curves. Let P and O be the points on the circles on opposite sides of F D, between which it is required to lay out the transition curve $\lambda = m\sqrt{\phi}$.

The angle between the tangents at P and O = a, say, and from the figure, $a_1 + a_2 = a$; and O P = l.

To find a_1 and a_2; from the circles $r_1 a_1$ = O D, $r_2 a_2$ = F P, and as s is small compared with l—

$$r_1 a_1 + r_2 a_2 = l,$$

also
$$a_1 + a_2 = a;$$

$$\therefore l = r_2 a_2 + r_1 (a - a_2),$$

but by transition curve equation (12)—

$$l = \frac{2 r_1 r_2 a}{r_1 + r_2}.$$

Equating these values—

$$\left.\begin{array}{l} a_2 = \dfrac{r_1 a}{r_1 + r_2} \\ \text{and similarly—} \\ a_1 = \dfrac{r_2 a}{r_1 + r_2} \end{array}\right\} \therefore r_2 a_2 = r_1 a_1 = \frac{r_1 r_2 a}{r_1 + r_2} = \frac{l}{2} \quad . \quad (25)$$

or the shortest distance bisects the transition curve in T; and it is only possible to lay out the portion (l) of the curve $\lambda = m\sqrt{\phi}$ bounded by radii r_1 and r_2, and tangential to the circular curve tangents at P and O when P and O are equidistant from and on opposite sides of the shortest distance s.

From the circles (neglecting squares of small quantities)—

$$PN = \frac{\left(\frac{l}{2}\right)^2}{2r_1} + \frac{r_2^2(a_1 + a_2)^2}{2r_1} - \frac{(r_2 a_1)^2}{2r_2} + s$$

$$= \frac{l^2}{8r_1 r_2}(r_1 + 3r_2) + s,$$

but putting $x = l$ in equation of cubic (17) the ordinate

$$PN = \frac{l^2}{6r_1 r_2}(r_1 + 2r_2)$$

$$\therefore s = \frac{l^2}{24 r_1 r_2}(r_1 - r_2). \quad . \quad . \quad . \quad (26)$$

$$\text{Again } PQ = PN - QN = \frac{l^2}{6}\frac{r_1 - r_2}{r_1 r_2} \text{ by } (17)$$

$$\therefore PQ = 4s \quad . \quad . \quad . \quad . \quad . \quad . \quad (27)$$

Similarly, putting $x = \frac{l}{2}$ in the first term of (17)—

$$TD = \frac{l^2}{48 r_1 r_2}(r_1 - r_2)$$

$$\therefore TD = \frac{s}{2}$$

or T is both the middle point of the shift s and the middle point of the transition curve OP.

In this case the length l cannot usually be fixed first, as in (a) of this section, but depends on the shortest distance s (see equation (26)).

The collected results for *Fig. 6* are—

Formulas (B).

$$\lambda + \lambda_1 = M\sqrt{\phi + \phi_1} \text{ (see 15).}$$

$$\rho = \frac{r_1 r_2 l}{\lambda(r_1 - r_2) + r_2 l}.$$

$$\frac{l}{a} = \frac{2r_1 r_2}{r_1 + r_2}.$$

$$y = M\left(\frac{(\phi + \phi_1)^{\frac{3}{2}}}{3} - \phi_1(\phi + \phi_1)^{\frac{1}{2}}\right) + \frac{2M}{3}\phi_1^{\frac{3}{2}}.$$

$$x = M(\sqrt{\phi + \phi_1} - \sqrt{\phi_1}).$$

$$y = \frac{x^3 (r_1 - r_2)}{6 \cdot l r_1 r_2} + \frac{x^2}{2 r_1}; \ \tan \phi = \frac{x^2}{2 l} \frac{(r_1 - r_2)}{r_1 r_2} + \frac{x}{r_1}.$$

$$s = \frac{l^2 (r_1 - r_2)}{24 r_1 r_2}; \ l = \sqrt{\frac{24 r_1 r_2 s}{(r_1 - r_2)}}.$$

$$PQ = OL = 4 \cdot s.$$

$$TD = \frac{s}{2}.$$

$$y_1 = \frac{x^3 (r_1 - r_2)}{6 l r_1 r_2} = \frac{4 \cdot s \cdot x^3}{l^3},$$

where y_1 is the ordinate measured from the circular curve, radius r_1. Hence, to set out this transition curve, find s on the ground, bisect s in T, the middle point of the curve; find l by the above formula; make $PT = TO = \frac{l}{2}$; O and P are the ends of the curve; $PQ = OL = 4 \cdot s$. Intermediate points can be set off from the circle r_1 or by ordinates from the tangent at O.

In all the preceding formulas (A) and (B) as applied to railway work, l may be taken as measured along the curve or along the axis of x. The intrinsic equations are exact. The Cartesian equations only represent the curve when ϕ is not great or l is small compared with $(r_1 - r_2)$, r_1 or r_2, and $\frac{s}{l}$ is small.

Numerical Example of $\lambda = m \sqrt{\phi}$, Figs. 4 and 5.—Let the super-elevation of the outside rail for maximum speed be 6 inches, then $l = 50 \times 6 = 300$ feet is an appropriate length of curve.

Let $r = 1{,}000$ feet.

Then $s = \frac{l^2}{24 r} = 3 \cdot 75$ feet.

$$a = \frac{l}{2 r} = \frac{3}{20} \text{ and } a^\circ = 8^\circ\ 35'.$$

$$\theta_1^\circ = \frac{a^\circ}{3} = 2^\circ\ 52'.$$

$$\rho = \frac{r l}{\lambda}.$$

$$= \frac{1{,}000 \times 300}{150} = 2{,}000 \text{ feet at middle of curve.}$$

$$\phi = \frac{\lambda^2}{m^2} = \frac{\lambda^2}{2 r l} = \frac{150}{4{,}000} = 0 \cdot 0375 \text{ at middle of curve.}$$

$$\therefore \phi = 2^\circ\ 9'.$$

$$y_1 = \frac{l^3}{3\,m^2} = \frac{l^2}{6\,r} = \text{ordinate at B.}$$

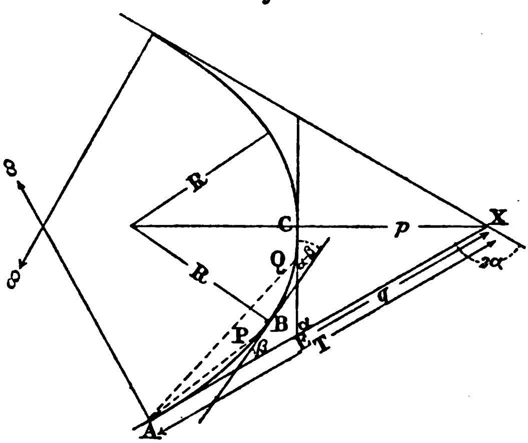
$$= 15 \text{ feet, also } = 4.s.$$

Maximum value of $z = \dfrac{2\,l\,a}{9\,\sqrt{3}} = 5 \cdot 8$ feet (from equation 24).

The error in taking $x = \lambda$ in this case, formulas (A), is not greater than $\lambda - x = \dfrac{\phi^2\,\lambda}{5\,\underline{|2}} = \dfrac{9 \times 300}{400 \times 10} = \dfrac{27}{40} = 8$ inches in 300 feet. This is negligible and will not practically affect any other element of the curve.

The reading of an article[1] on this subject, advocating a cubic, which appeared in *The Engineer* in 1868, has suggested to the Author the addition of the following diagram, *Fig. 7*, and corre-

Fig. 7.



sponding formulas for the "complete composite curve," or circle plus transition curve.

Complete Composite Curve.

If it is required to set out the complete composite curve, consisting of the transition curve and the circular curve, without having to displace by a parallel movement the circular portion or the original tangent, the required elements are easily obtained by the following formulas which refer to *Fig. 7*:—

[1] "On an Easy Curve for connecting Railway Tangents; with Tables adapted to setting-out by theodolite," by W. Airy. *The Engineer*, November 27 1868.

Length of transition curve $= l =$ curve A B.

$T = \frac{l}{2} + (R + s) \tan \alpha$; (chord A B, curve A B and abscissa A B $= l$, nearly; if not, see Eq. (9)).

$$s = \frac{l^2}{24 R}.$$

$$q = \frac{R \tan \frac{\alpha}{2}}{\cos \alpha} + \frac{2 s}{\sin 2 \alpha}.$$

$p = q \sin \alpha$; angle P A X $= \frac{\beta^0}{3}\left(\frac{A P}{l}\right)^2$; ($\beta$ small; if not, see Eqq. (9) and (10)).

$$C E = q \cos \alpha.$$

$$A E = T - q; \ \tan Q A X = \frac{(R + s) - R \cos \phi}{R \sin \phi + \frac{l}{2}},$$

$$\text{where } \phi = \alpha - \frac{Q C}{R} = \beta + \frac{Q B}{R}.$$

$$\beta = \frac{l}{2 R}; \ A B = l.$$

$$\beta^0 = \frac{l}{2 R} 57 \cdot 29 \ldots . \quad B C = R(\alpha - \beta) = R(\alpha^0 - \beta^0)\frac{1}{57 \cdot 29} \ldots .$$

Length of composite curve A C $= R(\alpha + \beta) = R(\alpha^0 + \beta^0)\frac{1}{57 \cdot 29} \ldots .$

Conclusion.

The Author has endeavoured to give such general methods of derivation of the curves with resulting formulas as will enable any practical problem to be solved within any required degree of accuracy.

Rankine in his "Civil Engineering," p. 655 *et seq.*, gives a few of the foregoing results, derived from the cubic, but without any explanation or indication of their derivation or working limits. The Author hopes his method of dealing with the subject may afford clearer views and further information respecting an interesting and highly useful application of higher curves to practical railway alignment.

The Paper is accompanied by drawings from which the Figures in the text have been prepared.

[Appendix.

APPENDIX.

As the Author abandoned the use of the cubic parabola with its limitations when he discovered the unlimited application and simple properties of the spiral $\lambda = m\sqrt{\phi}$, and only uses the cubic in this Paper as a first approximation, the following brief statement of the limiting properties of the cubic parabola and comparison of the elements of the two curves ($\lambda = m\sqrt{\phi}$ and $y = M x^3$) for such limits may be useful.

(*a*) *Cubic Parabola* $y = M x^3$ . . . . (1)

The radius of curvature ρ at any point x—

$$= \frac{(1 + 9\,M^2 x^4)}{6\,M x} \quad \text{. . . . .} \quad (2)$$

Evidently there is a value of x which makes ρ a minimum. Differentiating (2) and equating to zero, this value is found to be—

$$x_1 = \frac{0 \cdot 386074}{\sqrt{M}}.$$

The corresponding $y_1 = \dfrac{0 \cdot 057555}{\sqrt{M}}$.

The minimum value of $\rho = \dfrac{0 \cdot 5674}{\sqrt{M}}$.

If α = total deflection of curve at this point, then—

$$\tan \alpha = 3\,M\,x_1^2$$
$$= 0 \cdot 447213$$

Therefore $\alpha^\circ = 24^\circ\ 5'\ 41''$, and is constant for all cubic parabolas.

Therefore in any cubic of form (1) the radius of curvature decreases by a complex law (2) until $\phi = 24^\circ\ 5'\ 41''$, when it reaches its minimum value; it then begins to increase indefinitely following the same law. Hence the cubic is not suitable for railway curves beyond this limit.

The following expansion will give the length of the curve (1) measured from the origin:—

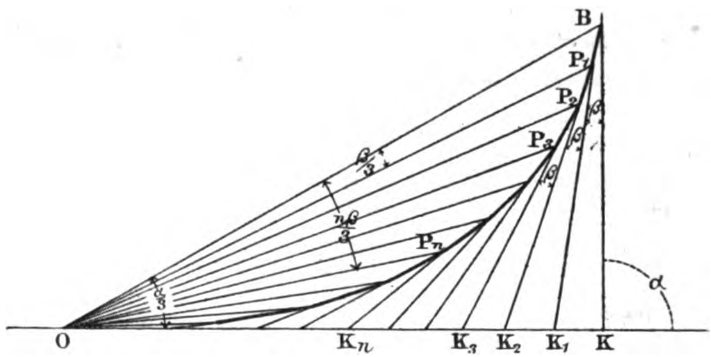
Length of curve $= x + \dfrac{9\,M^2 x^5}{10} - \dfrac{81\,M^4 x^9}{72} + \quad . \ . \ - \ . \ .$ (3)

(*b*) *The Spiral* $\lambda = m\sqrt{\phi}$:—This curve has no limitations with regard to ρ and ϕ, but for any required deflection there is a corresponding radius of curvature which is less than any which precedes it and greater than any which follows it, and at any point is given by the simple relation $\rho = \dfrac{\text{constant}}{\lambda}$. The expansions (9) and (10), rapidly converging for values of $\phi <$ or $= \dfrac{\pi}{2}$ (the maximum limit of any possible railway requirements), give the Cartesian co-ordinates

to any degree of exactness. The curve may also be easily traced by means of the equation $\phi = \frac{\lambda^2}{m^2}$ if relatively short chords be taken, which practically may be considered elements of the curve. The approximate relation $\theta = \frac{\phi}{3}$ is an exceedingly close approximation, giving an error of only half a minute in θ when $\phi = 24°$, and an error of 35 minutes when $\phi = 90°$. See next division (*c*).

The relation $\theta = \frac{\phi}{3}$ may be taken as sufficiently accurate for practical purposes, and affords a very simple method of tracing the curve for values of ϕ up to 90°.

Fig. 8.



In Fig. 8 let O be the origin of the curve, B a given point on the curve, and α the corresponding deflection angle.

Then $\angle$ B O K $= \frac{\alpha}{3}$.

Draw BK_1 making any conveniently small angle β with BK. Draw OP making an angle $\frac{\beta}{3}$ with OB and meeting BK_1 in P_1. Draw P_1K_2 making an angle β with P_1K_1, and draw OP_2 making an angle $\frac{\beta}{3}$ with OP_1 or $\frac{2\beta}{3}$ with OB and meeting P_1K_2 in P_2.

Similarly the points $P_3 \ldots\ldots P_n$ may be found; the points $P_1 \ldots\ldots P_n$ are on the curve, because for any point the angle $P_nOK = \frac{\text{angle } P_nK_nK}{3}$. The smaller the angle β is taken the more accurately the curve, as defined by $\theta = \frac{\phi}{3}$ will be set out.

By means of two theodolites, one stationary at O and the other moving from point to point, P_1 P_2 &c., the curve may easily be set out on the ground. A graduated cross-head would serve for the shorter sights, or the divergence β may be measured by an offset. It will be noticed that this method does not involve any linear measurements.

(*c*) *Comparison of Curves* $\lambda = m\sqrt{\phi}$ and $y = Mx^3$ in terms of the radius of curvature r at the limiting angle ($\alpha = 24° 5' 41''$) of the latter curve.

Let (a, b) and (h, k) be the co-ordinates of the points on the respective curves defined by r and α.

(i)	$\lambda = m\sqrt{\phi}$.	(ii)	$y = M x^3$.
If	$\alpha = 24^\circ\ 5'\ 41''$.	If	$\alpha = 24^\circ\ 5'\ 41''$.
Then	$a = r \times 0 \cdot 8273$.	Then	$h = r \times 0 \cdot 680$.
	$b = r \times 0 \cdot 1166$.		$k = r \times 0 \cdot 101$.
	$s = r \times 0 \cdot 0295$.		$s = r \times 0 \cdot 014$.
	$l = r \times 0 \cdot 8411$.		$l = r \times 0 \cdot 693$.
	$\tan \theta = 0 \cdot 14098$.		$\tan \theta = \frac{\tan \alpha}{3} = 0 \cdot 1491$.
	$\therefore \theta = 8^\circ\ 1'\ 28''$.		$\therefore \theta = 8^\circ\ 29'$.
	$= \frac{\alpha}{3}$ practically.		
	y at shift $= r \times 0 \cdot 0147$.		y at shift $= r \times 0 \cdot 006$.
	x „ „ $= r \times 0 \cdot 4205$.		x „ „ $= r \times 0 \cdot 273$.

(If $\phi = 90^\circ$ we get by (9) and (10) including terms, containing ϕ^6,

$$\tan \theta = 0 \cdot 56387$$
$$\therefore \theta = 29^\circ\ 25'.)$$

It is readily seen from the above that the relation $s = \frac{l^2}{24 r}$ only applies to the curve $\lambda = m\sqrt{\phi}$, and that generally the relations between the elements of this curve are much simpler and more easily expressed exactly than in the case of the cubic. For values of $\phi < 10^\circ$ say, the properties of the one curve may be applied to the other without appreciable error in railway work.

(*Paper No. 3172.*)

"Maintenance of Railway Tunnels."

By Arthur Watson, Assoc. M. Inst. C.E.

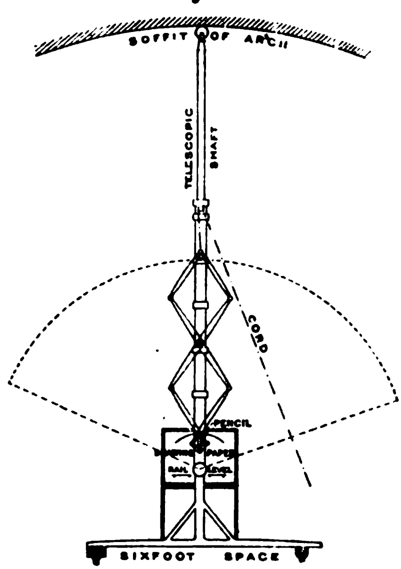
The question of the maintenance of tunnels commends itself to the special attention of engineers, since it concerns structures in which defects cannot be so readily detected, as in structures in the open. The Author proposes to indicate the lines upon which the best practice in the maintenance and repair of railway tunnels proceeds.

The van used for the purpose of examining a tunnel is open for three-fourths of its length, having a platform sufficiently raised to permit of the engineer getting as close to the roof and sides of the tunnel as possible, so that the men present can be continually sounding with hammers or mallets to detect cavities or looseness in the work. When these are discovered, dimensions are taken to locate the faults, and notes are made of the nature of repairs required. Water is undoubtedly one of the worst things to contend against, and places where large quantities are finding their way through the roof or sides are specially examined to see whether the material itself is perishing through this cause. This is of the greatest importance in old tunnels, where common bricks have been used in the construction, as they are found, with few exceptions, to be of soft material. Should the roof be bulging, a contour is made of the tunnel, in cross section, with an instrument designed on the pantagraph principle.

It consists of a tray or board, *Fig. 1*, 27 inches square, about 3 feet above rail-level, and supported by a frame resting on the two "6-foot" rails, the upper end of the vertical portion of which is on a level with the lower part of the tray. To this end is attached an arrangement of crossing bars with a telescopic shaft, which together form proportional dividers. On the upper end of the telescopic shaft is mounted a small wheel, which is passed round the soffit of the tunnel. On the front of the tray a piece of drawing paper is fixed, and on this is shown, in firm lines, the minimum structure of the railway. Through the first crossing

of the bars a pencil is placed, the point of which is kept in contact with the drawing paper by means of a spring, and when a cross section of the tunnel is required, the frame is clamped to one rail, a sheet of tracing paper is fixed on the tray, and the rail-level and vertical position are traced through. The telescopic shaft is now traversed round the soffit, and a correct contour is produced on the tracing paper to a scale of one-twelfth full size. The clearances can at once be measured with a scale, and instructions given for the centring ribs to be built, which will always clear the minimum structure.

Fig. 1.



INSTRUMENT FOR CONTOURING TUNNEL SECTIONS.

The timber uprights, bearing sills, centring ribs, blue and red bricks, cement, lamps, candles, oil, tools, ladders, planking, and all necessary ironwork, are first loaded into the ballast train at the stores, and conveyed to the site of the work. Should the work be close to the outside face of the tunnel, all material can be unloaded between trains during the week; but if the tunnel is a long one, or in a busy locality, or should the work to be done be situated at a greater distance from either end than ½ mile, the unloading must be done on Sunday, there being considerable risk in unloading and stacking materials in a hurry where, as often occurs, the clearance between the rails and the side walls is very limited. It is not desirable to place any material in the manholes, and on no account should anything be left in the "4-foot" space between the two running rails which would project more than 7 inches above rail-level. The bricks are stacked in the "6-foot" space between the running lines to a height not exceeding 2 feet 6 inches above rail-level, and the timber, lamps, tools, and planking where most convenient, whether in the "6-foot" or between the outside rail and the tunnel wall. The cement is stored in a waterproof shed outside

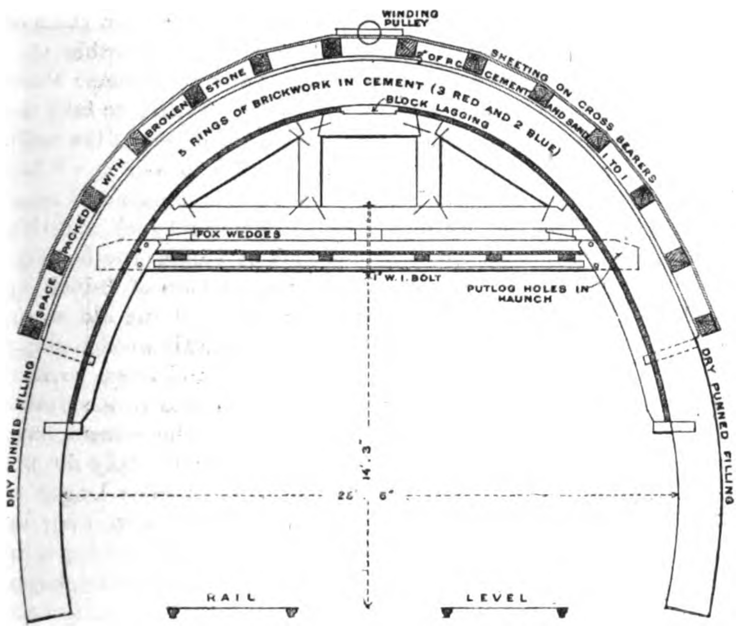
the tunnel, this shed having a planked floor, so that all cement can be turned over with shovels, and "air-slacked" before use. In no case must the supply be allowed to run short, as "green" cement is exceedingly objectionable for any class of work. The casks of oil, naphtha, gas, and petroleum are also stored in a convenient place outside the tunnel for the men to fill the lamps as they go in to their work. All the materials being now delivered at the site, the foreman in charge of the work goes into the tunnel, and, after ascertaining the portions to be repaired, proceeds to set out the position of the bearing timbers to carry the centring ribs, the underside of which must at no place be nearer to rail-level than 14 feet 3 inches, this being the clearance headway.

Square holes are then cut in the haunches of the soffit, to the required level on both sides, sufficiently deep to admit of easily and securely fixing the bearings for the centres. It may happen that the roof of the tunnel is not sound enough to support these timbers unaided, and in such cases it is best to give them independent support by cutting chases in the side walls and haunches, and inserting vertical 9-inch by 9-inch timbers for that purpose. Care must always be taken to keep these and other timbers at least linable with the tunnel walls, for should any mishap occur, whereby a case of merchandise is detached from a goods train, and, coming in contact with these upright timbers, dislodges them, the result would be disastrous. These timbers are fixed about 6 feet apart, centre to centre, this being the safest length of roof to reconstruct in one operation. Of course, the nature of the repair, in all cases, governs the spacing of the centres, and this may be much less than the length quoted when the roof and haunches appear treacherous. The work of cutting out the "putlog" holes for the bearing timbers can be done during the week, provided, of course, that the men are protected by flagmen on both lines of way. These flagmen are stationed at least half-a-mile in advance of the workmen in the direction of approaching traffic in long tunnels, and are provided with a bell-pull near at hand, which conveys a warning by wire to the bell fixed near the workmen; as an additional safeguard they blow a whistle. The warning thus given is sufficient to permit of the men descending and removing their ladders before the arrival of the train.

When the bearing and other timbers, centres, &c., have been cut or built to the required length or size, the first convenient Sunday is chosen, and notices are inserted in the works programme for the complete blocking of both lines of way between specified

hours. The bearing timbers and centring ribs are hoisted into position by means of a single-legged derrick, fixed in the "6-foot" space. The intervening space between the centres is planked over, and forms a platform for the carpenter to stand on while setting the centres to a correct level. This is done by means of fox-wedges, placed on the top side of the bearing timbers, carrying the bottom member of the centring rib, *Fig. 2*. This arrangement is very convenient for removing them on completion.

Fig. 2.



Scale, ⅛ inch = 1 foot.

CENTRING RIBS AND BEARING TIMBERS.

The ribs are bolted to the bearing timber, and a packing is inserted in the space between them through which the bolt passes. This method not only obviates any risk of the centres settling should the wedges, by any means, become slack, but it also gives a stiffness to the rib. It is not advisable to "dog" the wedges together, as there is often difficulty in slackening the centres when this practice is resorted to. The centres are constructed with two vertical Queen posts, thus giving the workmen more space to pass through and to convey material to the work.

It frequently happens that the contour of the arch soffit differs in the same tunnel, although it may be a continuous section. If the difference is not very considerable, the old roof is cut out sufficiently to allow of a uniform section being substituted throughout. But if, on the other hand, the difference is such as would involve much additional excavation of rock, shale, or earth, above the roof, two sets of centring ribs are made to the different contours, and the reconstruction arranged to let each gang work towards the other, and at a convenient distance, say four lengths of 6 feet. Before these ultimately meet, the exact difference in contour is ascertained, and, by altering the top and side sweeps on three of the centres, one section is gradually developed into the other.

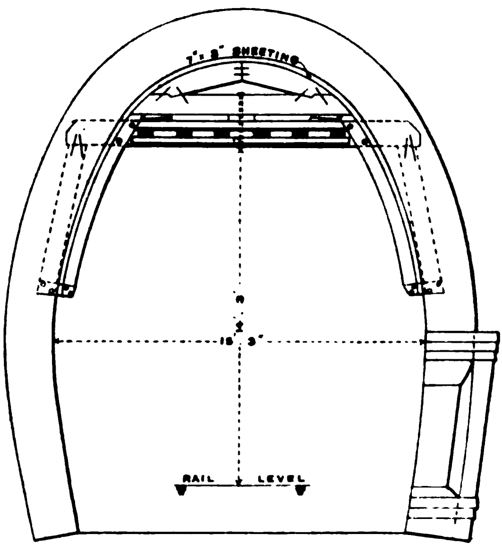
The first men to commence the work proper are miners; these cut out the roof in short lengths, timbering the arch to take the thrust as they proceed, commencing along the crown of the soffit, and proceeding down towards the haunches and springing. When the roof is excavated sufficiently for the proper number of rings of brickwork, it is closely poled with 6-inch by 1-inch sheeting in short lengths, butted together on 6-inch by 1-inch cross bearers; these, in turn, being carried by running timbers of 8-inch by 8-inch scantling, supported from the extrados of the old work, *Fig.* 2. The excavated material is loaded into small wooden skips, lowered through a hole in the working platform down to rail-level, and wheeled to tip in the "6-foot" space in a suitable position for the ballast train to load it. When the miners have cut out the entire width to be re-lined, and all is ready for the bricksetters, they commence to cut out another short length of 6 feet, not adjacent to the length the bricksetters are working in, but 6 feet further on, thus leaving the intermediate length of 6 feet undisturbed until the first portion is re-lined and keyed in, for convenience in timbering the roof.

The centring ribs are now accurately set to the required height with the fox-wedges, and 7-inch by 3-inch laggings are laid on as required, and the new work is brought up from both springings or haunches simultaneously, so as to equally load the centring, and also "key in" on the crown of the arch, proper attention being paid to the gauging of the bricks to ensure the keying course being tight, and this can only be satisfactorily done by working out the gauge, and telling the bricklayer what he must set his courses to. If $3\frac{1}{16}$-inch bricks are used, four courses will gauge $13\frac{1}{4}$ inches when laid. At about four courses on each side of the centre line of the tunnel, the longitudinal 6-foot laggings are discontinued, and cross 1-inch block laggings substituted; these

are of 7-foot by 3-inch timbers, with rebates sunk in the ends, fitting in corresponding rebates in the longitudinal laggings. The bricksetter proceeds to the blank end of his work, supposing it is against a finished section, and commences "keying in," laying the cross block laggings as required. In this way the work is completed, as he works outwards. Of course, if there is a long length of tunnel to be re-lined, which must of necessity be accomplished in many short stages, the unfinished ends are always left with 4½-inch toothings for bonding into the succeeding lengths. One serious difficulty always will occur if the work is confined to the central, or even any, portion of the tunnel, which does not finish at the outside face of all, because the majority of tunnels are constructed with ashlar voussoir quoins at their outside faces, and these rarely if ever require renewal. This difficulty lies in the "keying in" of the last length of arch over the crown, in dimensions about 2 feet in both cross and longitudinal section. It is practically impossible to "rack" the arch rings in this closing piece, as in doing this there would be no space left in the face rings to pass the bricks up into the back rings; and this is most apparent when one considers a tunnel with say six arch rings. The remotest ring in this case is at least 2 feet 5 inches from the upper surface of the laggings, and it is at once apparent that a bricksetter, working under the conditions obtaining in tunnels, of imperfect light and limited space, might not trouble to make a good bond unless closely watched. The method usually adopted is what is termed "pigeon-hole" bond, meaning that the keying bricks are jammed in lengthwise and square to the coursing joints of the other bricks in such a manner that, if a whole brick will fit, this serves for the "key," and if not, "closers" are cut to suit. Of course, conditions become more favourable for good work the nearer the face rings are approached, until fairly good bond may be expected in the second and third rings, and perfect bond in the face or soffit. A method by which better results can be obtained is to use bonding straps of wrought iron, cut in short lengths, and forced into the bed joints of the rings with sufficient frequency to prevent the bricks tilting downwards. The bricksetter can then place his bricks to rest on these, and give each a full bed and joint of cement mortar before placing it in position. Uniform bond is thus obtained and the straps built in. This operation, again, requires very close supervision, otherwise it will not be carried out satisfactorily, as there seems but little margin for doubt that the majority of "falls" in tunnel-roofs have occurred at those points where, on examination, it has been found

that "pigeon-hole" bond, or, more correctly, no bond at all, has been resorted to. As the work of re-lining proceeds, the cavity between the 1-inch sheeting to the roof and the crown of the outside ring is packed solid with "scaplings" and broken brick, or sometimes, when the roof appears treacherous, with cement concrete. The 8-inch by 8-inch running timbers are drawn for use elsewhere as the packing proceeds, but the sheeting is never drawn if once put in. The centres are struck between 4 days and 7 days after the arch has been turned complete, and are then removed forward to do service in a fresh length.

Fig. 3.



Scale, ⅛-inch = 1 foot.

CENTRING RIBS FOR SINGLE LINE TUNNEL.

The foregoing remarks apply to all classes of tunnels, whether double or single line, the only difference being that in single line, *Fig. 3*, the centring rib is somewhat simpler in design, and does not allow much space for the passage of the men or material through its framing. In this case arrangements are made for a trap door in the 1-inch planking between each of the centres.

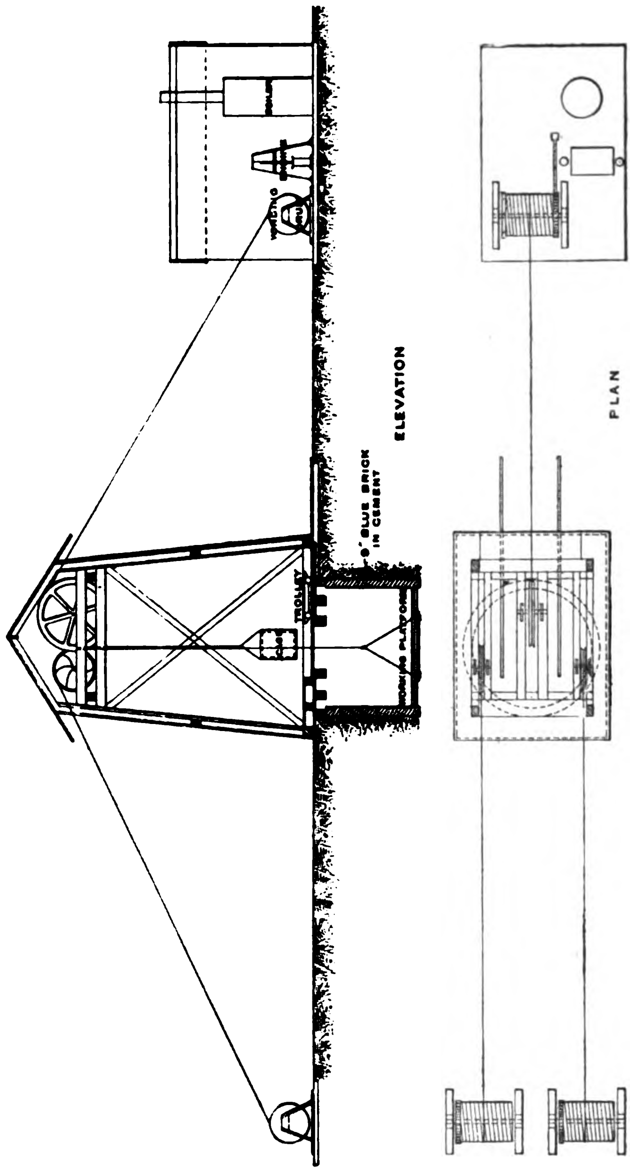
It must not be supposed that the only maintenance work done in tunnels consists of entirely re-lining them, as this is not the case. Frequently the arch-rings and walls are in good repair in a general sense, but small areas require attention. These chiefly consist of loose or perished bricks in the face rings or side walls which can easily be replaced and put in good order. This work is done on Sundays in busy neighbourhoods; and between trains, on week-days, on suburban lines; it does not necessitate the erection of any centring, since all that is required can be done by the men working on a scaffold fixed between ladders. The perished bricks

are cut out and are replaced by new ones; the loose rings are made secure by forcing pieces of slate between the joints and all is made good with mortar composed of cement and sand in equal parts.

The early types of tunnels had no provision for the refuge of the platelayer from passing traffic, but in later years it has been considered necessary to allow for this in the construction of new works, and also to provide them in the existing tunnels as opportunity offers. In the latter case the side walls are cut out, and manholes are formed in blue brickwork set in cement mortar. These occur alternately about every 15 yards along each side of the tunnel.

In constructing tunnels it is often necessary to commence operations at several points along the centre-line simultaneously, and for this purpose shafts are sunk from the surface of the ground above. These may become air-shafts for the proper ventilation of the tunnel when the works are complete, and remain open; but circumstances have often arisen whereby they have been bricked up on the completion of the work, owing to objections raised by the inhabitants of the neighbourhood to the smoke emitted from them. In the course of years the objections have been lost sight of, and the railway company's engineer has been able to open them out again. When this is done, the same methods are employed and the same tackle is used as when shafts are repaired or relined. The first thing is to ascertain whether the shaft is truly vertical, by plumbing down into the tunnel, and should it be out of line, allowance must be made in setting the timber framing to permit of the shaft being rebuilt in its correct position. A timber shed is fixed over the shaft, being framed with rough-sawn timber, with the outside close boarded to keep weather out, and as a safeguard against trespassers or others getting near the shaft, should the work be left for any period. A method of carrying out this work, which has proved very successful, is to fix three large pulleys or wheels on bearing timbers, resting on and bolted to the frame of the shed at a convenient height, *Fig. 4*, above the ground-level at the top of the shaft. The largest wheel is about 6 feet in diameter, and over this a steel-wire cable, $\frac{5}{8}$-inch in diameter, passes, carrying the skip or cage. The cage is of timber, measures 2 feet 3 inches by 2 feet 3 inches by 3 feet and is banded round with $2\frac{1}{4}$-inch by $\frac{3}{8}$-inch wrought-iron formed into eyelets at the upper corners for the sling chains attached to the cable to hook on. These wrought-iron bands must always pass completely around to make certain of the strength of the cage bottom. The front face is constructed to slide in two parts for convenience in loading

Fig. 4.



Scale, $\frac{1}{16}$ inch = 1 foot.

ARRANGEMENTS ABOVE GROUND-LEVEL.

or unloading. The two smaller wheels or pulleys are used to raise or lower the working platform on which the men and material stand during the progress of the work. The platform is made as large in diameter as the shaft will admit easily, and is suspended at both sides by cables passing over the two smaller pulleys and fixed to two winches, placed sufficiently far away to obtain a flat pitch on the cables. A 12-HP. vertical engine with 8-inch cylinders is connected to a winding drum 3 feet 6 inches in diameter for raising and lowering the cage, and is checked by a lever foot-brake, the wood cleat of which grips round one end of the drum. Special attention is paid to the engine driver's view of the shaft-head, as his haulage varies daily, and there is always a risk of overwinding. It is of advantage to have an opening at each side of the engine shed, in line with the sight of the driver, and so placed that the cage, when raised, will obstruct his view, and, when lowering, hand-signals can be easily seen. Again, the larger the pulleys are, within reason, the less wear there is on the cables, and the cage, not being heavy, has a tendency to foul when the pulley is revolving rapidly; this is minimised by large pulleys. In raising the material, the loaded cage is hauled out of the shaft sufficiently high to allow the small trolley, *Fig. 4*, to be pushed under it, for trucking in and out of the shed. The trolley forms, when at rest, a complete cover for the well-hole in the flooring, and its size must always be the gauge of the hole, allowing for lap. Should the shaft be of considerable depth, it is well to fix pieces of steel rail across the opening, at a depth of about 12 yards, so that should any mishap occur to the working platform it would be impossible for it to fall the entire depth of the shaft.

The renewal of the brickwork is commenced at the top and proceeds downwards in depths varying from 18 inches to 8 feet, and in widths of 4 feet. The old work is taken out and made good with blue brickwork in cement at once, gauging the bricks to underpin perfectly tight, and "driving" the top bricks, in succession, as the circuit is worked round. Templates to the radius of the shaft, and about 5 feet in length, are used, and the new work is 9-inch blue brickwork in cement, with dry lining at the back to prevent the water wash. No timber curbs are used to build the brickwork upon, as they rot away and eventually cause the brickwork to settle. When 4½-inch brickwork is met with, the shaft has to be timbered in 5-foot settings with 12-inch by 6-inch walings, 9-inch by 9-inch uprights, and 9-inch by 4½-inch running timbers behind the walings to wedge the cleats

against the 1-inch sheeting; this done, the 9-inch work is set as before.

In illustration of the foregoing, the following are particulars of repairs carried out in the manner described. Cases 1 and 2 refer to double-line tunnels; and Cases 3 and 4 to single-line tunnels.

Case 1.—This tunnel was constructed in 1850, through loose earth and shale. The arch was turned in five half-brick rings of red brickwork. In course of time, through insufficient packing in the heading above the arch and also through indifferent workmanship, the arch settled badly and lost its original shape. Bricks began to drop, and at times small portions of the roof fell; these were temporarily repaired in cement, and loose bricks were wedged up, but eventually the relining of the tunnel had to be considered as a safeguard against disaster.

Case 2.—This tunnel was constructed in 1849, through loose rock. The arch was turned in block-in-course masonry, and backed with rubble. Examination made where the different lengths had been joined showed careless work in many instances, the result being that the earth above settled and forced the arch with it. Large masses of masonry fell from the roof and haunches from time to time, and as a satisfactory result could not be obtained by patching, it was decided to cut out the old work and to reline in blue brickwork.

Case 3.—This tunnel was constructed in 1852, through hard rock. The arch was turned in four half-brick rings. No provision had been made for conducting the drainage down the haunches; so, finding its way through the arch, it washed all the mortar out of the joints and weathered the bricks, which were of inferior quality, so badly as to necessitate relining the arch in blue brickwork in cement.

Case 4.—This tunnel was constructed in 1868, through loose earth and shale. The original arch was composed of five half-brick rings, but the workmanship was inferior, and the material was so poor that it weathered away under the action of moisture, and becoming too costly to maintain, it was relined in blue brickwork set in cement.

COMPARISON OF COST.

Double Line Tunnels.—Renewal.

—	Length of Work. Linear Yards.	Square Yards per Linear Yard.	No. of Rings of Brickwork Renewed.	Nature of Traffic.
Case 1	79	$12\frac{1}{3}$	5	Heavy
„ 2	42	12	5	Moderate

Cost per Linear Yard.

Case 1.

	£	s.	d.
Materials	18	18	2
Labour	20	5	0½
Engine Power	0	8	3
Ballast Wages	0	8	10
	35	0	3½

Case 2.

	£	s.	d.
Materials	7	16	1½
Labour	10	12	4
Locomotive Power	0	12	11
	19	1	4½

Cost per Square Yard.

	£	s.	d.
Case 1	2	16	9
Case 2	1	11	9

Single-Line Tunnels.—Renewal.

—	Length of Work. Linear Yards.	Square Yards per Linear Yard.	No. of Rings of Brickwork Renewed.	Nature of Traffic.
Case 3	161	11½	5	Light
„ 4	43½	14	5	Fairly Heavy

Cost per Linear Yard.

Case 3.

	£	s.	d.
Materials	6	3	9½
Labour	8	3	4½
Locomotive Power	0	15	2
	15	2	4

Case 4.

	£	s.	d.
Materials	11	15	8
Labour	17	8	9
Engine Power	0	14	0
	29	18	5

Cost per Square Yard.

	£	s.	d.
Case 3	1	6	3
Case 4	2	2	9

The Author is indebted to Mr. W. B. Worthington, M. Inst. C.E., Engineer-in-chief of the Lancashire and Yorkshire Railway, for permission to use the information contained in these pages.

The Paper is accompanied by four drawings from which the Figures in the text have been prepared.

(*Paper No. 3212.*)

"The Vacuum System of Low-Pressure Steam-Heating."

By Edward George Rivers, Assoc. M. Inst. C.E.

In the year 1882, an interesting Paper on "American Practice in Steam-Heating,"[1] by the late Robert Briggs, M. Inst. C.E., occupied the attention of the Institution, details of the several systems then in vogue being exhaustively discussed. Since that time the evolution of steam-heating in the United States has advanced very considerably, and the Author, in placing before the Institution a description of the latest developments of low-pressure heating upon the vacuum system, feels that a very important stage of the matter has been reached.

Before proceeding to deal with the main subject of the Paper, the Author would briefly refer to the generally accepted principles which govern the circulation of steam in heating apparatus of the type hitherto in use. To quote the words of Mr. Briggs, "The cause producing the circulation throughout the pipes of the warming apparatus is solely the difference of pressure which results from the more or less rapid condensation of the steam in contact with the radiating surfaces; a partial vacuum of greater or less amount is thereby formed within the radiating portions of the apparatus, and the column of steam or of water equivalent to this diminution of pressure constitutes the effective head producing the flow of steam from the boiler, while the return current of condensed water is determined by the downward inclination of the pipes for the return course." In considering the application of these principles it becomes evident that, as the loss of heat through the walls of the radiators is a slow process, the general circulation resulting from a feeble vacuum must necessarily be very sluggish, even assuming that this low vacuum could be maintained. There is, however, an important factor in the case to which insufficient attention has hitherto

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[1] Minutes of Proceedings Inst. C.E., vol. lxxi., Session 1882–83, Part i.

been directed in practice, namely, the production of gases in working, which not only tend to negative a vacuum, but are likely to establish a resistance to the flow of steam to the radiators. Steam flowing through a pipe traverses the tubular space at a rate dependent upon the excess of its pressure over the resistance encountered; if, therefore, all sources of resistance be removed and a better vacuum be maintained, it is evident that the efficiency of circulation will be largely increased. It is curious to note that, although engineers have correctly viewed a steam-heating apparatus as a condenser, they have never hitherto suggested the provision of an obviously necessary appliance required for the proper working of a condensing plant, viz., the air-pump or its equivalent. It is to the recognition of this important point that the success of the vacuum system is due.

The systems of steam-heating which were in vogue at the date of Mr. Briggs' Paper may be classified as follows: (1) the high-pressure system with gravity returns, sub-divided into one- and two-pipe systems; (2) high-pressure supplies reduced to low pressure at the radiators or coils; (3) low pressure upon the downward supply principle; (4) exhaust steam systems with varying back pressure upon the engines. All these systems were open to objection, especially Nos. 1 and 4. The latter sometimes took the form of a straight run of pipes to the outer air from the main exhaust pipe, unchecked by any controlling device, and in these circumstances back pressure became a negligible quantity; but when attempts were made to use exhaust steam in a controllable form of apparatus the back pressure became a serious factor in the case. This attempt at the utilization of exhaust steam afforded no solution of the problem of utilization without waste. The principal defects in the pressure systems are: (1) noise in working; (2) impossibility of controlling the temperature of the radiators; (3) leaks developed as the result of excessive pressure in the radiators; this is generally traceable to the imperfect working of the reducing valves. These difficulties induced engineers to turn their attention to the utilization of exhaust and low-pressure steam in another direction, viz., by passing it through tubular heaters supplying the ordinary type of hot-water apparatus. This was in some respects an improvement as far as control of temperature is concerned, but there still remained a waste of steam, coupled with back pressure upon the engines. This indirect method of heating by exhaust steam is still much in vogue in this country.

In the year 1882 attention was directed to the vacuum system of circulating low-pressure steam by the introduction of the

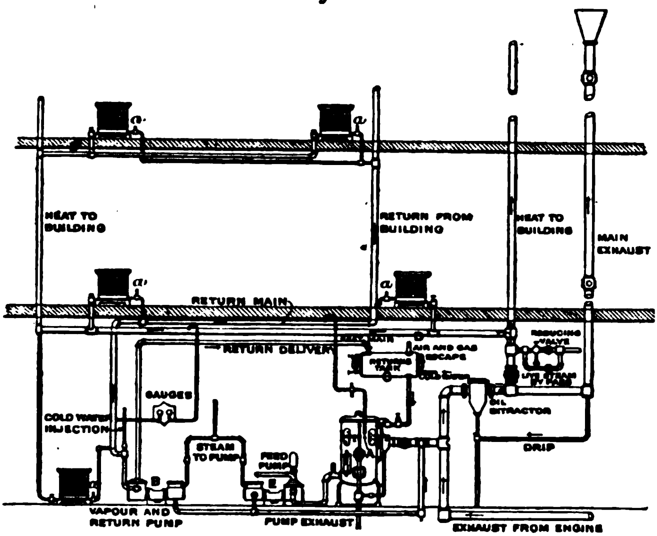
Williames apparatus, embodying this principle, but the practical application of the system was not a success, owing to the absence of efficient appliances for the prevention of "short circuiting" of the steam circulation. This omission has been met by the systems devised by Paul and by Webster. Both of these systems are based upon the principle of inducing the circulation of steam at or below atmospheric pressure by the removal of air and gases from the radiators, but the means by which this result is secured differ in each case. In the Paul system air and gases are removed by a vacuum- or return-main of small diameter, the water of condensation being drained back by gravitation through the steam-supply mains. The outlet valves from the radiators to the return main are automatic in action, and they close when steam is in contact with them. The vacuum in this system is induced by a steam ejector.

The general principle of the Webster system follows that of the Williames and Paul systems, but the vacuum in the return-mains is maintained by a running pump delivering into a receiver, from which the water of condensation is returned to the boiler, while the gases escape to the outer air. The system can be worked in two ways, either by utilizing exhaust steam, or by live steam reduced down to a pressure of about ¼ lb. per square inch above atmospheric pressure. Under the first arrangement the steam is taken from a branch of the main exhaust pipe, the latter being taken up to the outer air in the usual way, and the outlet being fitted with a special valve relieving at a pressure of ¼ lb. per square inch above that of the atmosphere. The following conditions then present themselves. If the whole volume of the exhaust is not utilized in the heating system, the surplus escapes, and the function of the valve need not be taken into consideration; but if the apparatus is sufficiently extensive to take the whole exhaust, the closing of the valve at the main outlet becomes imperative, in order to prevent a breakage of the vacuum in the return mains. The latter condition approaches nearest to practical efficiency. In the first case there is no appreciable back pressure upon the engine, while in the latter the working is improved to the extent of the vacuum maintained in the return mains—between 5 inches and 10 inches.

The general arrangement of the engine-room appliances is shown in *Fig. 1.* A branch of the exhaust supply is taken through a feed-water heater (A), fitted with an oil separator, and is then passed into the horizontal main, from which the vertical supplies are taken to the several floors of the building, the inlet of steam to

the radiators being controlled by screw-down valves of the ordinary pattern. In order to secure a complete circulation of steam through

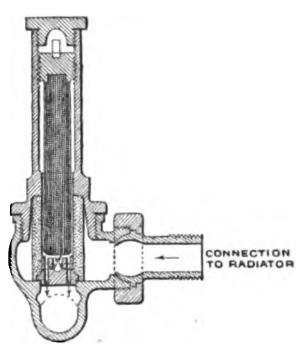
Fig. 1.



General Arrangement of Engine-Room Appliances.

an extensive system of heating coils, so that those coils most remote from the boiler or engine receive their supply with the same facility as those close to it, a special contrivance for automatically governing each radiator becomes necessary. This requirement is provided for in the Webster system by the thermostatic valve shown diagrammatically in *Fig. 2.* Its action is dependent upon the expansion of a spindle or stalk of rubber compound, held at one end in the body of the valve, and free to expand lengthwise and to close upon the raised seating at the bottom outlet for condensed steam and gases. When adjusted it allows the water collected at the outlet of a radiator to follow the vacuum pull in the return main, but as soon as the following steam impinges upon it, it closes, and does not open until condensed steam at a lower temperature is again in contact

Fig. 2.



Automatic Valve.

with it. Each radiator receives its supply of steam at the moment of opening of the thermostatic valve. The supply ceases on the closing of this valve, and is not resumed until the loss of heat through the walls of the radiator, producing condensation of the steam, causes the valve to open again. These valves are used to drain all rising mains, and they are also fixed at all points in horizontal supplies where a difference of level causes a "drip." One of the standard size is capable of draining the condensed steam from 200 square feet of heating surface. The Author has had these valves under careful observation in working, and they appear to be very reliable. As a special test, one of these small appliances was placed on the drip outlet of the steam-heating apparatus in the drawing offices at Messrs. James Simpson & Company's factory, in place of a large size steam-trap. It has not been adjusted in any way since fixing, and its action is perfect.

The return mains in the Webster system are much smaller than those used with two-pipe pressure systems. The average diameter is $\frac{3}{4}$ inch in the former, as compared with $1\frac{1}{2}$ inch in the latter. The vacuum pump shown at B in *Fig. 1* is of the "wet type." The pattern chiefly used in the United States is the "Deane," but for installations in England a new pattern, designed by the Worthington Pumping Engine Company, has been adopted. The average speed of the pump is about sixty strokes per minute, and the exhaust steam is taken into the heating main. The speed is automatically regulated by a "vacuum governor" of special design. The pump is connected to the general return main, and delivers into the receiver C, from which the gases escape to the outer air by the pipe D. The condensed water is then passed through the heater A, and is returned to the boiler by the feed-pump E. In general practice a pump having a steam cylinder of 6 inches in diameter will deal with the condensation from 20,000 square feet of radiating surface.

A special feature of the vacuum system is the control of the temperature of the radiators. One of the principal objections urged against steam-heating hitherto has been the impossibility of controlling the heat otherwise than by entirely shutting off a section of the apparatus, large coils being frequently arranged in sections, each with its commanding valve. Under the Webster system, this objection is entirely removed, and radiators can be kept at any desired temperature between 90° and 212° F. No air-valves are required, and there is no possibility of "water hammer" in working. In practice it is sometimes desirable to

place a portion of the radiation apparatus upon the basement floor of a building at a level below that of the return-main to the pump, in which circumstance it is possible under this system to lift the condensation several feet above the point to be drained, thus avoiding the necessity of keeping the return-main in a trench.

Very large installations of the low-pressure systems have been working in the United States for some years with most satisfactory results. The total space heated in two buildings of recent construction in Philadelphia (the Stephen Girard and the Snellenberg buildings) amounts to 5,000,000 cubic feet, and an installation at the town of Pullman may be taken as an example to show the facility with which steam is conveyed in a horizontal direction. The school building, one of the numerous structures heated, is 3,100 feet distant from the engines. This installation was first worked with steam at a pressure of 60 lbs. per square inch, but as a satisfactory result was not obtained, it was converted into a low-pressure system upon the Webster principle.

A converted pressure system at the Knightrider Street branch of the Post Office Savings Bank, London, is specially interesting from the fact that it utilizes exhaust steam which has previously passed through a tubular heater working the hot-water apparatus in another section of the building, and also through a feed-water heater. An extensive installation of the Webster system has recently been fitted at the Parcel Post Depôt, Mount Pleasant, Clerkenwell, a portion of the exhaust from the electric lighting engines being utilized for the working.

The quantity of exhaust steam sent to waste in this country, when it could be profitably utilized in the warming of buildings, is astounding, and the Author feels that, with the introduction of a thoroughly practical and scientific system for dealing with these waste supplies, the attention of engineers will be specially directed to the extension of steam-heating. The difficulty of distribution to remote points having been successfully overcome, the heating of buildings from a central generating station by underground mains should prove commercially successful. The exhaust steam from electric lighting stations in good residential neighbourhoods might easily be made a source of profit, especially in such localities as the Kensington quarter of London, where buildings containing residential flats are numerous.

In the Author's opinion the vacuum system most thoroughly disposes of all the objections hitherto attaching to steam-heating. The advantages may be summarized as follows:—

(1) It is more efficient and more economical in working than hot-water apparatus on a large scale, especially when exhaust steam can be used.

(2) Perfect circulation can be secured, and the heat can be rapidly raised, and as rapidly lowered.

(3) It is free from noise in working, and requires a minimum of attention.

(4) The heat from the radiators is controllable.

In connection with the general constructive features, the Author would indicate the extensive use of malleable cast-iron elbows, bends, tees, &c., in American practice. These are specially suited to the work, and are neat in appearance. The principal points in connection with an efficient radiator are: (1) complete accessibility of the whole surface for cleaning; (2) secure joints to the loops; (3) easy replacement of any loop which may become defective. All complex patterns with grouped loops should be avoided. It is instructive to note that in American practice the heating apparatus in a building is taken into consideration at an early stage and structurally provided for, instead of being left until the eleventh hour, as is too frequently the case in this country. Much unnecessary cutting away is therefore avoided, chases in walls being provided for rising mains, and these are covered with expanded metal and plastering after all joints have been tested. Screwed joints in pipe lines are generally made with graphite. In reference to cost there is little difference between the vacuum systems and the pressure systems.

The Paper is accompanied by two tracings, from which the Figures in the text have been prepared.

(*Paper No. 3151.*)

"Experiments on Steam-Jets."

By Walter Rosenhain.

The increasing use of the steam-turbine has attached fresh importance to the phenomena attending the efflux of elastic fluids under pressure through orifices and nozzles, and has rendered necessary the revision of experimental and theoretical data on this question. Designers of steam-turbines have probably made experiments on this question, but no accounts of such experiments have been published. According to the generally accepted theory of the efflux of elastic fluids, the velocity of efflux is independent of the external pressure when that pressure is less than half the internal pressure; but there is good reason to believe that with expanding nozzles this is not the case, since it is known that the addition of a condenser considerably increases the efficiency of a De Laval turbine.[1] This implies that the energy of a steam-jet discharging from a high boiler-pressure into a vacuum is greater than that of the same jet discharging into the atmosphere.

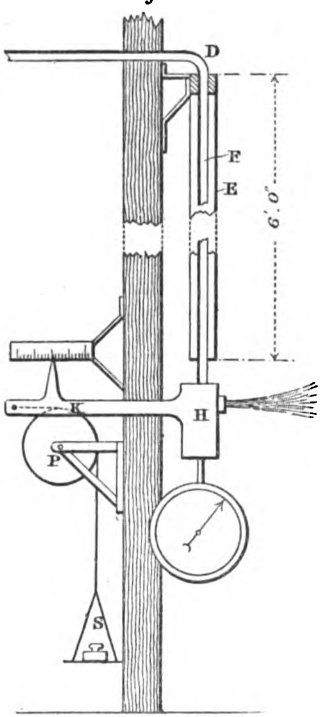
The experimental and theoretical papers which have been published on the subject of the efflux of gases and of steam lead to the general conclusion that theoretical analysis, on thermodynamic and hydrodynamic principles, is possible when frictional resistances are neglected and a law of expansion is assumed. To adapt the equations so obtained to the results of experiments, coefficients are introduced as in hydraulics, and for moderate pressures these coefficients correspond closely to those found for the discharge of water through similar orifices. Further, theory and experiment appear to be agreed that with a constant high pressure a limiting velocity of efflux is reached when the lower pressure has been reduced to between 50 per cent. and 60 per cent. of the high pressure, while no limiting value is indicated when, with a constant low pressure, the higher pressure is increased. The experimental conclusions, however, only apply to orifices in

[1] *Engineering*, 26th November, 1897.

thin plates or convergent nozzles of various types, including a short cylindrical tube, while theoretical conclusions, especially with regard to the limiting velocity, apply only to the narrowest section of a nozzle. Neither can be directly applied to conically divergent nozzles.

From consideration of the published records of experiments, it appeared desirable to measure the velocity of the steam as directly as possible, and to avoid estimating the density of the steam at the point of efflux. This estimation, depending upon temperature measurements, the Author regards as the weak point in previous experiments. Further, for steam-turbine purposes the velocity required is the actual velocity attained by the steam on leaving the nozzle, and not merely a figure in feet per second from which the mass discharged could be calculated when the area of the orifice and the density of the steam are known. It is therefore necessary to measure both the mass discharged and another quantity involving the velocity. For this second quantity the momentum of the escaping jet was chosen as being most readily measured. In some preliminary experiments it was attempted to measure this momentum by allowing the jet to impinge upon a semi-cylindrical bucket or vane in such a way as to reverse the jet; the pressure on the vane should then be equal to twice the momentum given to the jet per second. For several reasons this method was, however, rejected and the reaction method was adopted. The boiler used was of the locomotive type. The apparatus employed is shown diagrammatically in *Figs. 1* and *2*. A well-lagged steam-pipe D, $\frac{3}{4}$ inch in internal diameter, was connected with a vertical elastic tube F, consisting of a piece of weldless drawn steel cycle-tubing $\frac{5}{8}$ inch in internal diameter, the point of junction being rigidly supported. The

Fig. 1.



APPARATUS FOR MEASURING THE MOMENTUM OF A STEAM-JET.

tube F was provided with an air-jacket D E, formed by a tube of larger diameter open at the bottom, thus allowing the elastic tube considerable play. The elastic tube carried at its lower end a cylindrical chamber H, having on one side, as shown in *Fig. 2*, a circular opening into which the nozzles were screwed. It will be seen that the axis of the escaping steam-jet was horizontal, and that its reaction would deflect the tube F. This reaction was resisted by means of weights placed in a scale-pan S, carried by a cord passing over a pulley P, and having its end fixed to two horizontal arms K, attached to the chamber H (*Fig. 1*).

The pulley P was a very fine steel disk running on ball-bearings so nearly frictionless that the errors due to this cause were insignificant. Owing to the difference in weight of the various nozzles, weights were placed in the scale-pan at the beginning of each series of experiments such that the pointer indicated zero when the apparatus was hot, but no steam was passing. The constancy of this zero was verified at intervals during the course of each series of experiments.

The steam-pressure in the chamber H was measured by a gauge of the Bourdon type, graduated to 2 lbs. per square inch, which was tested, before, at intervals during, and after the experiments. No attempt was made to read beyond the nearest pound, and the results for pressures below 20 lbs. per square inch are, therefore, liable to inaccuracy. At lower pressures some preliminary experiments were made with a much more sensitive gauge upon which $\frac{1}{10}$ lb. could be estimated, and it was found that a change of 0·2 lb. in the pressure produced a noticeable deflection of the reaction index.

Various methods of using the apparatus were tried. One method was to begin with the boiler-pressure very low and to keep the valve completely open, thus allowing the steam to escape continuously from the nozzle while the boiler-pressure rose gradually. The weights in the pan were increased step by step and the gauge pressure at which the reaction of the jet exactly balanced the weights in the pan was observed for each step. During the course of such a run the pet-cock in the chamber was opened at intervals, but very little water was found to accumulate. By judicious stoking, the rate at which the boiler-pressure rose could be adjusted, and the time of rising from 0 to 200 lbs. per square inch varied between 4 hours and 1 hour. No difference in the results could be detected, although the conditious as to priming must have differed considerably. The chief objection

to this method of working is that it renders the conditions of observation very trying, on account of the enormous quantity of steam discharged into the room, and the deafening roar of the discharge.

To avoid this inconvenience a second method was tried. The number of observations on each run was reduced so as to allow of the steam being shut off between two observations. In this case care was required to see that the apparatus was thoroughly hot and free from water when each observation was taken, but with this precaution the method was found quite as satisfactory, and far more convenient than the first. In both cases, however, a single run occupied an entire day, as it took 8 hours to 10 hours for the steam-pressure to fall from 200 lbs. per square inch to zero; hence a third method was tried—obtaining the desired pressure at the gauge by throttling the steam at the valve. The only observable difference between the jet at full way and by throttling to the same pressure was in the appearance of the jet. The throttled jet, when the throttling was considerable —as from 200 lbs. per square inch to 20 lbs. per square inch —was of a darker colour, much more transparent, but showing the brown colour by transmitted light much more strongly; at the same pressure not the slightest difference in the reaction could be observed between a "full-way" and a "throttled" jet.

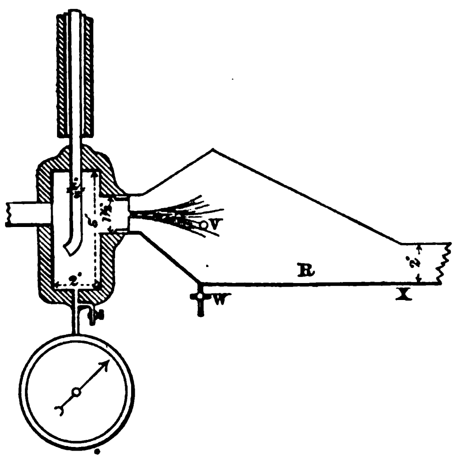
In consequence of these observations, the mode of experiment adopted for each nozzle consisted in first obtaining a fairly complete series of observations by either of the first two methods described, and then, with the boiler at or near its full pressure, verifying a number of the observations by means of throttling. These observations were repeated on another day after the zero-adjustments, &c., had been verified. In some of the later series of experiments the number of observations on each nozzle was very considerably reduced.

All the observations of reaction recorded were made with a boiler-pressure that was either steady or rising. This method of working was adopted because the pressure was more under control when rising. To test the matter, however, several sets of observations were made with falling pressure, but no differences in the results were observed. The reactions having been determined for each nozzle, the next step was to measure the discharge in pounds per second for these same nozzles, and it was necessary to do this under conditions as nearly as possible those of discharge

into the atmosphere. For this purpose the cord and pulley were removed and the pipe F was clamped in position, while over the nozzle was fitted a vessel of tinplate, shown in section and in position at R in *Fig. 2.* This vessel was connected to a pipe X, which led to a surface-condenser, and was fitted with a U-tube used as an open manometer; at W, and at the lowest point of the pipe X, pet-cocks were provided. The air-pump was worked by a small engine. The pressure in the chamber R could be regulated by means of the pet-cocks, so that it did not differ from atmospheric pressure by more than 3 inches of water.

The desired pressure at the experimental gauge having been obtained, it was kept constant to the nearest pound by regulating the fire and the feed, and also by a stop-valve; the air-pump and circulating water were started, and the whole was allowed to run for some time, the condensed water being allowed to escape by a drain. With a little experience it became possible to judge, from the appearance of the water and the behaviour of the gauges, when the steady state had been reached. When this had been the case for some time a stop-watch was started, and simultaneously a cock was turned which led the condensed water into a galvanised-iron vessel standing on a platform-balance. This vessel already contained a quantity of cold water, and the whole was accurately counterpoised. As soon as the experiment had begun, the counterpoise was increased by 5 lbs., and the time which elapsed till the weight of the vessel was again sufficient to raise the lever was noted; this was repeated for each addition of 5 lbs. This observation was not capable of any great accuracy, and was only made to act as a check on the final weighing, and it served to indicate any unusual occurrence, such as a leakage, &c. The leakages that

Fig. 2.



APPARATUS FOR MEASURING THE DISCHARGE.

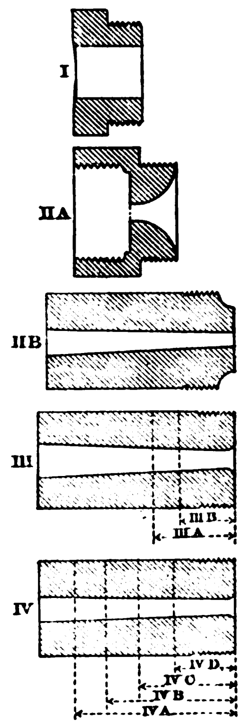
occurred at several points were carefully collected, and added to the water in the weighing-vessel at the end of each run. Further, immediately before each experiment all the drain-cocks were opened wide for several minutes. The same was done immediately after the conclusion of each experiment, the condensed water running from them being added to that in the weighing-vessel. In all cases, when about 30 lbs. of water had been condensed, the stop-watch was stopped, and the cock was reversed, so as to turn the condenser-discharge into the drain. As regards the accuracy of the observations, an error of 1 ounce in the weighing is unlikely, and would only affect the result to 1 in 3,000. The time of an experiment varied between 55 minutes and 7 minutes, and the stop-watch registered $\frac{1}{5}$ second, so that the greatest error would be 1 in 1,000. The variations in the actual results are of the order of 1 per cent., and this is probably due to the variable amount of water left in the condenser at the beginning and end of an experiment.

The greatest difficulty arose with the regulation of the steam-pressure, but after the boiler-attendant had become accustomed to the regulation of the fire and the manipulation of the valve, variations of more than 1 lb. per square inch during the course of an experiment could be avoided. Possible sources of serious error in these experiments are leakages in the condenser. The arrangements for the circulating water were carefully tested by allowing the circulating water to flow under full pressure and then working the air-pump without allowing any steam to enter the condenser. No leakage could be detected. Variations in the speed of the air-pump were found to have no influence on the results. With regard to the effect of throttling, priming, and working with rising or falling pressure, the same remarks apply as in the case of the reaction experiments, so that the present experiments confirm the conclusion of Wilson and Parenty that the amount of moisture in the steam does not affect its behaviour during discharge.

To test whether the presence of a receiver would affect the jet, some experiments were made with the apparatus as fitted up for reaction measurements. With the pointer at zero, a number of obstacles were placed in the path of the jet or close to it. Thus the point of a penknife, with the broad side of the blade across the direction of the jet, was moved along its axis. In some cases no effect was produced on the pointer till the knife was so close to the nozzle that it became difficult to decide whether it had already

touched it or not, but in two cases there was a very marked effect at a short but perceptible distance further away, and this was associated with certain peculiarities in the appearance of the jet; however, at an inch from the nozzle a sheet of metal deflecting the entire jet had no effect on the reaction. Enclosing the jet in a tube or cutting off the air-draught from the rear by a card attached to the nozzle also had no effect. It was therefore concluded that a receiver such as that shown in *Fig.* 2 would not affect the formation of the jet.

Fig. 3.



SECTIONS OF NOZZLES.

The nozzles shown in section in *Figs.* 3 were of gun metal, and were carefully prepared to exact dimensions. No. I is an orifice in a thin plate, produced by a very oblique chamfer on the outside. No. II consists of two parts drilled and turned up together. All the experiments with this nozzle as a whole were completed before the parts were separated to form the new nozzles IIA and IIB. Nos. III and IV were made of approximately the same length as IIB, and with larger and smaller tapers respectively. No. III was then cut down to form IIIA, the greatest diameter of which is equal to that of IV. Finally IIIA was again cut down to form IIIB. No. IV was also cut down by $\frac{3}{8}$ inch at a time to form IVA, IVB, IVC, and IVD successively. In III and IV the inner edge of the nozzle is merely rounded off smoothly. These were designed on lines suggested by the results of the experiments on II, IIA and IIB. The area of the orifice or nozzle does not enter into the calculation of the velocity. In order, however, to make the results strictly comparable, the entire set of nozzles was made with as nearly as possible the same least diameter, $\frac{3}{16}$ inch. This diameter, and the tapers, approximate to those used on a De Laval 5-HP. turbine motor. A Table showing the dimensions of the nozzles as supplied with this turbine is appended for the sake of comparison. The actual least diameter of each nozzle has been carefully measured with a micrometer microscope to an accuracy of 0·001 inch.

EXPERIMENTAL NOZZLES.

Number.	Least Diameter.	Greatest Diameter.	Length.	Taper.	Remarks.
	Inch.	Inch.	Inch.		
I	0·1873	..	..	..	Orifice in thin plate.
II	0·1840	0·287	2·1	1 in 20	Compound nozzle.
IIA.	0·1866	..	0·5	..	Inlet half of II.
IIB.	0·1849	0·287	1·6	1 in 20	Outlet half of II.
III	0·1882	0·368	2·16	1 in 12	Inlet edges slightly rounded.
IIIA.	0·1882	0·255	0·79	1 in 12	
IIIB.	0·1882	0·241	0·64	1 in 12	
IV	0·1830	0·255	2·16	1 in 30	
IVA.	0·1830	0·242	1·785	1 in 30	
IVB	0·1830	0·230	1·41	1 in 30	
IVC.	0·1830	0·217	1·035	1 in 30	
IVD.	0·1830	0·205	0·66	1 in 30	

DE LAVAL NOZZLES FOR 5-HORSE-POWER TURBINE.

Pressure.	Least Diameter.	Length.	Taper.
Lbs. per Square Inch.	Inch.	Inch.	
136	0·157	1·57	1 in 17·4
105	0·163	1·57	1 in 21·4
Experiment IIB.	0·184	2·11	1 in 20·0
100	0·197	1·57	1 in 19·0
60	0·230	1·57	1 in 29·0
58	0·256	1·57	1 in 26·6

The formula used for the calculation of the velocity of the steam in the jet is—

$$V = \frac{Wg}{M}$$

where V is the velocity of the steam in feet per second,
W is the reaction in lbs. weight,
g is the acceleration of gravity, taken at 32·2 feet per second, per second,
M is the mass of steam discharged per second in lbs.

From the description of the experiments it will be seen that W and M are measured directly. For purposes of calculation, points were plotted on squared paper showing for each nozzle—

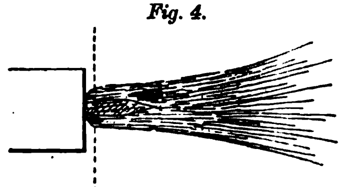
(*a*) Steam-pressure as abscissa, W as ordinate.

(*b*) Steam-pressure as abscissa, M as ordinate. From the smooth curves drawn to represent these points values of M and W were taken and used in the above formula to give values of V; and finally a third curve was plotted, showing—

(*c*) Steam-pressure as abscissa, V as ordinate. This last curve represents the relation between pressure and velocity, and also serves as a check on the accuracy of the arithmetical calculations.

The formula used assumes that at the point where the velocity is measured the steam has reached atmospheric pressure, otherwise the reaction would be increased by the remaining pressure. In other words, the velocity here determined is that attained by the steam on reaching atmospheric pressure where this occurs outside the nozzle, or its velocity on leaving the nozzle where atmospheric pressure is attained within the nozzle; in the latter case the steam may lose some of its momentum by friction against the nozzle after its expansion is completed. For practical purposes it may be taken that the velocities here found correspond to the kinetic energy of the jet on leaving the nozzle—a statement justified by observations on the shape of the jets. With the exception of those from the two very short nozzles, No. IIIB and No. IVD, the jets—even that from No. I—are very nearly parallel for several inches from the end of the nozzle, or at most diverge at approximately the same taper as the nozzle.

Fig. 4.



JET FROM VERY SHORT NOZZLE.

In the case of the expanding nozzles this shows that the steam is expanded to atmospheric pressure before leaving the apparatus. With Nos. I and IIA the explanation is not so evident, but the phenomena support the views of Wilson and Parenty that even through such openings the steam does not flow with either the density or the pressure which obtains on the high-pressure side of the orifice. These observations of the shape and appearance of the jet were made repeatedly with great care, and the boundary of the jet was determined by sounding with a steel point, the trembling of which instantly indicated when it had entered the jet. The jet was often distinctly visible up to the orifice. Especial care was given to these observations because the Author was aware that what is here recorded is at variance with the photographs of steam-jets published with Parenty's Paper. The jets are there shown as parabolic in form with the apex at the orifice, the jet spreading out very rapidly on leaving the orifice. The only approach to this appearance that the Author could obtain, *Fig. 4*. occurred with the very short nozzles Nos. IIIB and IVD, but even here the jet, in proportion to its size, did not spread to anything like

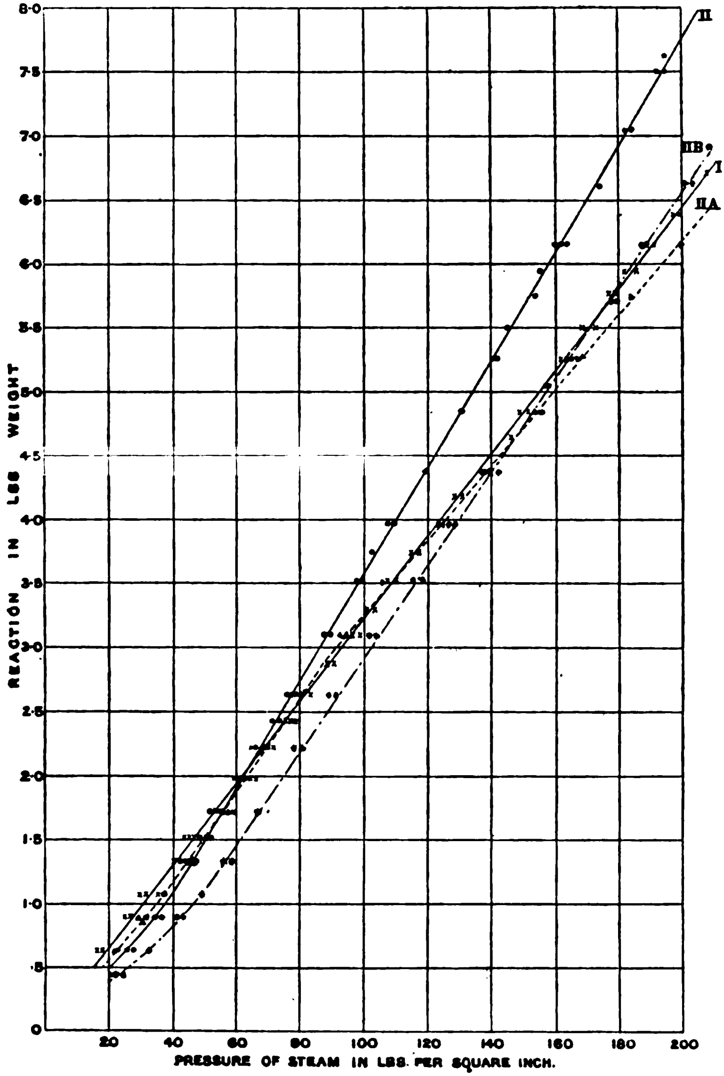
the extent shown by Parenty. It will be seen that at first the lateral expansion is rapid, and that then the jet becomes almost parallel. Two further peculiarities were observed with these two jets. An obstacle placed in the path of the jet at the place indicated by the dotted line, or nearer to the nozzle, instantly affected the reaction of the jet, but further out no effect could be produced. With the jets that showed no external spreading, an obstacle as here indicated produced no effect on the reaction even when removed and replaced at intervals timed to synchronize with the period of swing of the apparatus. The second peculiarity was that they showed a marked and peculiar structure somewhat resembling a blow-pipe flame in appearance. Such differences in the visibility of various zones of the jet point to differences in the mode or amount of condensation taking place there, and it would therefore seem that the quantity of water in the steam has a bearing on this question. A further fact in this connection is found in Sauvage and Pulin's Paper on the discharge of water from steam-boilers. The photographs of these hot-water jets bear a striking similarity to Parenty's plates, the hot-water jets spreading out still more rapidly than the steam-jets shown by Parenty.

The first series of curves, *Figs. 5*, *8*, and *11*, represent the experiments made with nozzles Nos. I, II, IIA, and IIB. The reaction curves, *Fig. 5*, are mostly straight lines, *i.e.*, the reaction is simply proportional to the pressure, but the constants vary for different nozzles. In the case of No. I—"orifice in a thin plate"—the curve is a straight line through the origin, while for all other nozzles the line could only reach the origin by a curve. With IIA there is a slight but distinct sinuosity in this curve, and the points of IIB show a tendency to something similar. This peculiarity was verified by repeating the experiments under varied conditions. It appears to be due to friction, as the sinuosity occurs only in those two nozzles where the friction would be large; in comparing the curves representing reaction and discharge of these nozzles it should be remembered that the minimum diameters of II, IIA and IIB are identical, but that of No. I differs very slightly.

The discharge curves, *Fig. 8*, occupy approximately the positions one would have expected. The nozzle having an easy inlet and an expanding outlet gives the greatest discharge, the inlet being evidently more important than the outlet, hence the near approach of IIA to I. The position of IIB so far below I seems to show that the sharp inlet is unsuited to passing a large quantity of

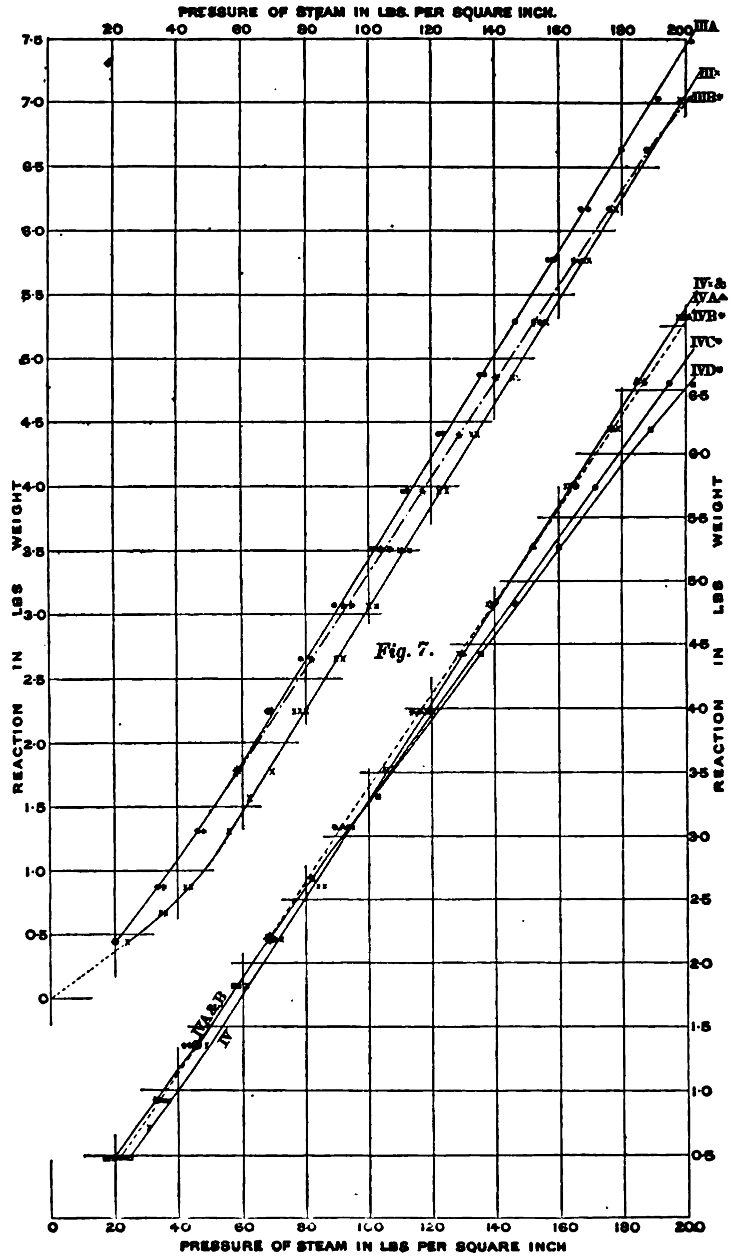
steam through an expanding nozzle. The velocity curves, *Fig. 11*, on the other hand, show that the quantity of steam passed by a

Fig. 5.



nozzle depends very considerably on the shape of the inlet, while the velocity of the steam on leaving the nozzle depends more on

Fig. 6.


PRESSURE OF STEAM IN LBS. PER SQUARE INCH.
REACTION IN LBS WEIGHT
IIIA
III
IIIB
IV &
IVA
IVB
IVC
IVD
IVA&B
IV
Fig. 7.
PRESSURE OF STEAM IN LBS PER SQUARE INCH

the shape of the outlet portion. This points to the conclusion that the density of the steam at the narrowest section depends upon the shape of the inlet, and that this density for a given internal pressure is greater with a well-rounded inlet than with a nozzle having a sharp inner edge. This accounts at once for the most conspicuous feature of this set of velocity curves, viz., that up to a pressure of about 80 lbs. per square inch the greatest velocity is attained by a jet from an "orifice in a thin plate" and that above 100 lbs. per square inch IIB, having a sharp inlet, gives a greater velocity than II, which has a rounded inlet and the same outlet. Apparently a rounded inlet admits a greater weight of steam to the narrowest section than the orifice or nozzle can deal with efficiently. The advantage of I over IIA thus arises from its smaller discharge, the smaller quantity of steam being able to expand with greater freedom and consequently to develop a greater velocity than the denser steam issuing from IIA.

From the point of view of the kinetic energy developed per pound of steam, the velocity curves may be taken to represent the "efficiency" of the various nozzles. The effect of a sharp inlet is then to reduce the density of the steam at the narrowest section, and hence less steam is passed, but the steam that does pass is fully or almost fully expanded, and hence, though the discharge is reduced, the efficiency is increased. In consequence of this conclusion all the later nozzles were designed with an inner edge only slightly rounded off.

The curves in *Fig. 11*, though they do not actually become horizontal within the range of the experiments, appear to be asymptotic to horizontal lines, but they do not entirely exclude an inclined asymptote.

On comparing the nozzle No. IIB with those in actual use on Laval turbines, it was found to lie midway between extremes. The Author therefore designed nozzles Nos. III and IV, which represent more extreme cases. Then, in order to separate the effects of taper and length of the expanding cone, No. III was cut down until its expansion was equal to that of No. IV; this nozzle is called IIIA. *Fig. 12* shows the velocity curves of nozzles Nos. III, IIIA, and IV. *Figs. 6, 9*, and *13* give the reaction, discharge, and velocity curves respectively of nozzles III, IIIA, and IIIB. *Figs. 7, 10*, and *14* give the corresponding curves for nozzles Nos. IV, IVA, IVB, IVC, and IVD.

From *Fig. 12* it appears that the greater length of IV is a disadvantage at high velocities, and this would point to designing such nozzles with a large taper so as to obtain the necessary

expansion in as short a length as possible; but the Author is not inclined to increase the taper beyond 1 in 12 or 1 in 10. A comparison of the results of IIIA and IIB shows a very small difference in favour of 1 in 12 as against 1 in 20, so that no great

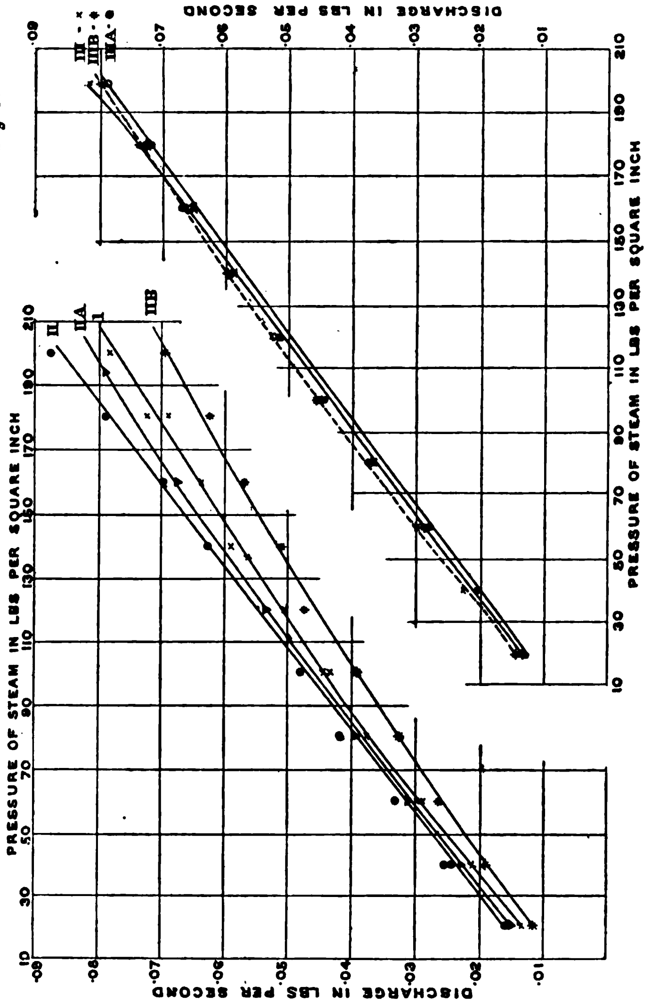


Fig. 9.

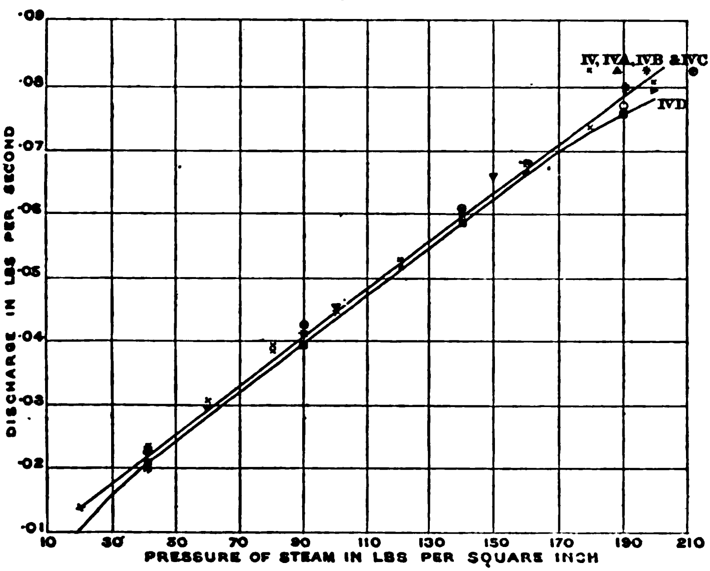
Fig. 8.

gain is to be expected from larger tapers, while a stage can be reached beyond which the jet no longer fills the cone. Comparing III, IIIA and IV it is seen that a taper of 1 in 30 is too small and that the expansion of III is too great for the highest pressures

here used. The velocity of 3,060 feet per second found for IIIA at 200 lbs. per square inch is the highest attained in these experiments. It is probably more than a mere coincidence that this should be almost exactly the same as the highest velocity of a rifle bullet obtained by Prof. R. V. Boys.[1] The air in the rifle barrel in front of the bullet is obviously under conditions similar to those of the steam in a nozzle.

In view of the considerable effect of reducing the length of III to that of IIIA, the latter was further cut down to form IIIB. From *Fig. 13* it is at once evident that the best form of nozzle for

Fig. 10.



this taper lies, for all pressures, somewhere between III and IIIB, probably not very far from IIIA. It should be noted that the discharge and reaction curves, *Figs. 9* and *6* respectively, are all strictly comparable, as the inlet and narrowest section are the same, and were carefully protected from injury or interference while the nozzle was being cut down. The relation of the reaction curves to one another is similar to that of the velocity curves, but the discharge curves show the peculiar feature that IIIA lies slightly but consistently below III and IIIB. In the

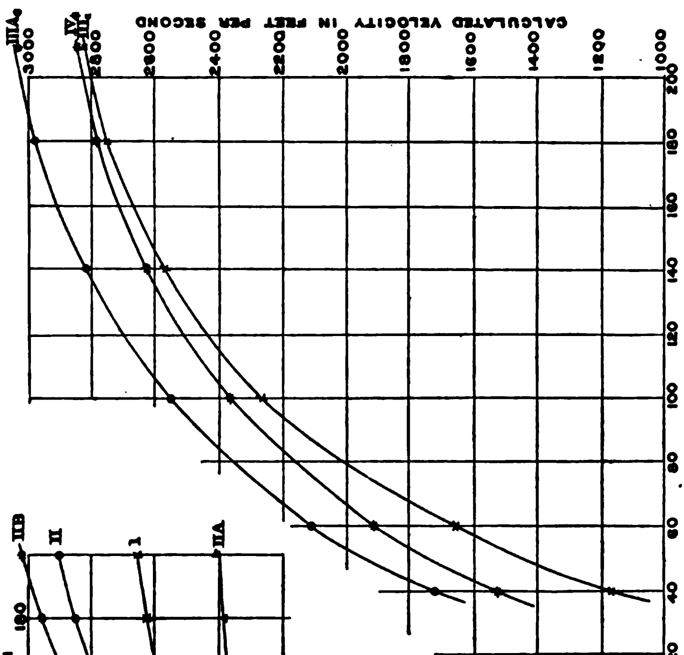
[1] See *Nature*, 2nd March, 1893.

case of IIIB, the expansion of which is very insufficient, this is not surprising, and for III the explanation probably is that it corresponds to too great an expansion. It may be supposed that the steam expands down to atmospheric pressure, and then flows through the remaining portion of the nozzle much as an incompressible fluid would do, the stream increasing in section at the expense of its velocity. The discharge would not be sensibly reduced in this way, but the velocity would fall off, and the greater efficiency of IIIA would be accounted for. Proof of this explanation could only be furnished by data as to the discharge of this nozzle into a vacuum or partial vacuum; according to the present view, the reaction and velocity should be greater when discharging into a vacuum, but the mass discharged should not be affected to anything like the same extent.

Nozzle III having been cut down by rather large steps, it was sought to throw further light on the question by cutting down No. IV by $\frac{3}{8}$ inch at a time, successively producing the nozzles Nos. IVA, IVB, IVC, IVD. For these it was thought sufficient to determine only a few points on each curve, *Figs. 7*, *10*, and *14*, which show the reaction, discharge, and velocity at the nozzles. In order, however, to present the results more clearly, the curves of *Fig. 15* were plotted. Here the length of nozzle is taken as abscissa, and reaction, discharge, and velocity are taken as ordinates for separate curves, which have been plotted for steam-pressures of 50 lbs., 100 lbs., 150 lbs., and 200 lbs. per square inch. These curves show that reaction and discharge are influenced by the length of the nozzle in opposite ways. Very long nozzles with low steam-pressure, or, more generally, nozzles that tend to cause over-expansion produce a large discharge but comparatively small reaction—thus confirming the explanation given of the peculiarities of *Fig. 9*.

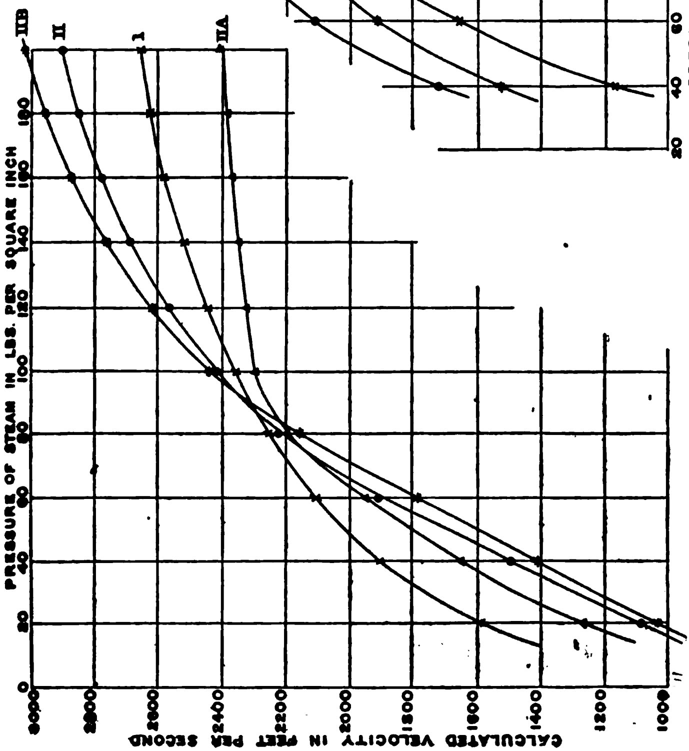
The reaction curve at 100 lbs. per square inch shows a maximum at IVA which recurs more markedly in the corresponding velocity curve. Taking the "efficiency" of a nozzle in the sense already defined, it will be seen that the most efficient form of nozzle varies with the pressure. The shape of the curve at 50 lbs. per square inch indicates that for these low pressures a long expanding cone is distinctly bad; in fact, a comparison of *Figs. 11*, *12*, *13*, and *14* shows that up to 80 lbs. per square inch an orifice in a thin plate is more efficient than any form of nozzle used in these experiments.

At 100 lbs. per square inch the velocity curve shows both a maximum and a minimum. A maximum was to be expected;



CALCULATED VELOCITY IN FEET PER SECOND
PRESSURE OF STEAM IN LBS PER SQUARE INCH
IIIA
IV
III

Fig. 12.



PRESSURE OF STEAM IN LBS. PER SQUARE INCH
CALCULATED VELOCITY IN FEET PER SECOND
IIB
II
I
IIA

Fig. 11.

the minimum, however, can only be accounted for by supposing

Fig. 14.

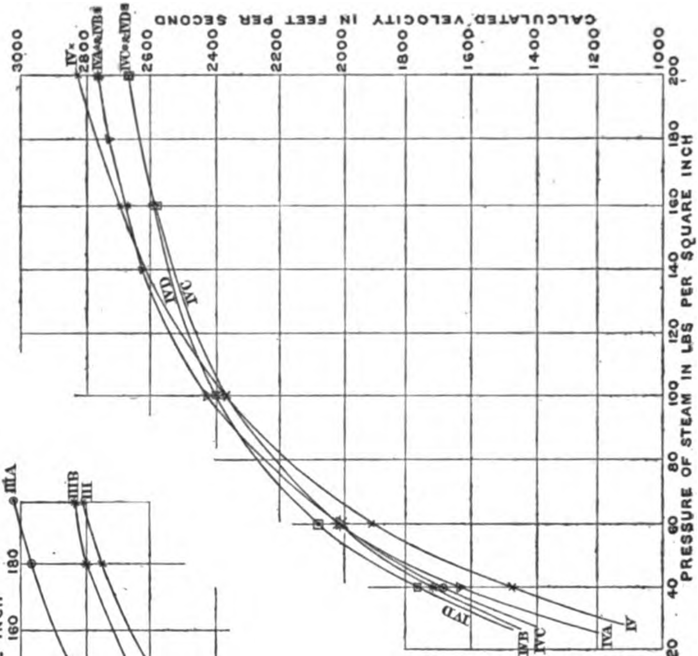
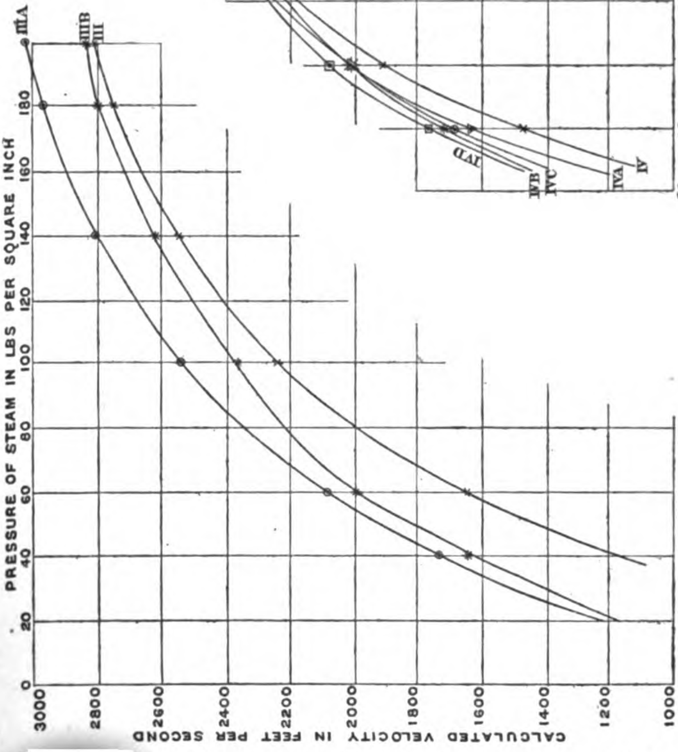
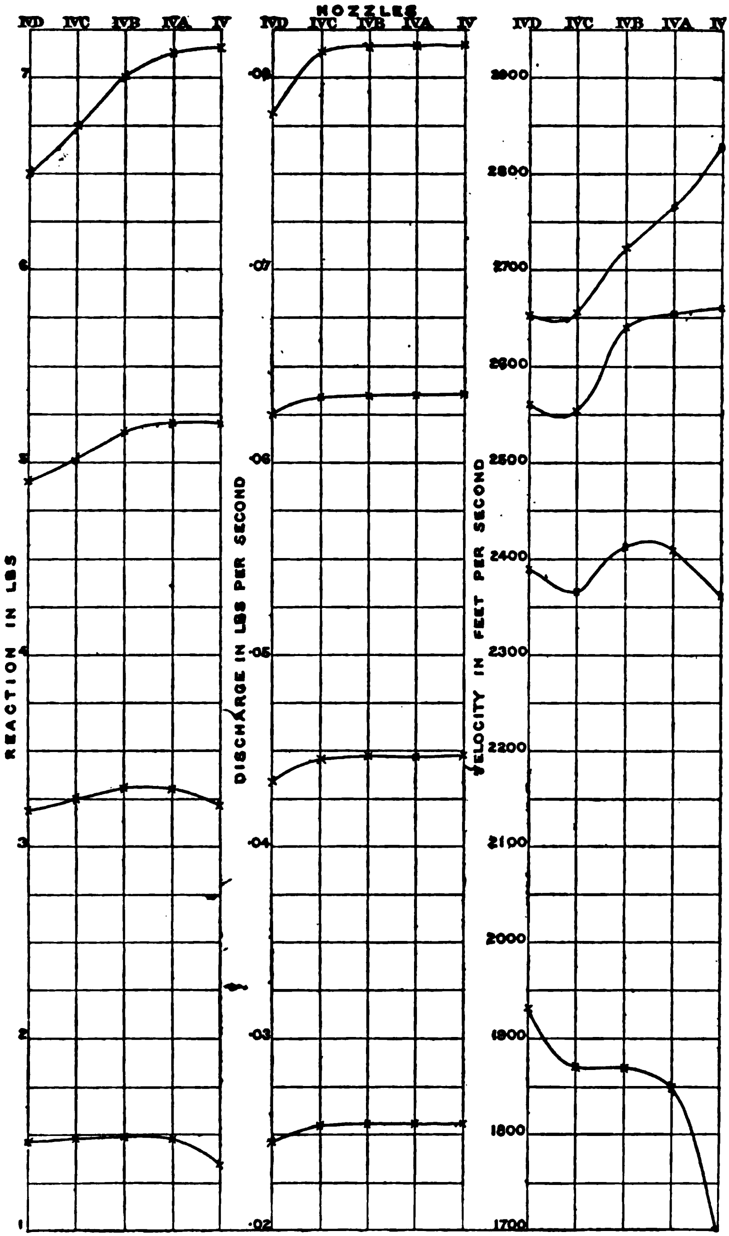


Fig. 13.



th[illegible] of length from IV$_D$ to IV$_C$ brings the discharge

Fig. 15.


NOZZLES
IVD IVC IVB IVA IV
IVD IVC IVB IVA IV
IVD IVC IVB IVA IV
REACTION IN LBS
1
2
3
4
5
6
7
DISCHARGE IN LBS PER SECOND
·02
·03
·04
·05
·06
·07
·08
VELOCITY IN FEET PER SECOND
1700
1800
1900
2000
2100
2200
2300
2400
2500
2600
2700
2800
2900

up to the highest value attainable for this pressure, while neither IVc nor IVb are long enough to develop the full reaction. The fall in the velocity curve from IVa to IV is another case of "over-expansion," more especially as it disappears at 150 lbs. per square inch. Here the minimum has moved towards IVd, and it practically disappears at 200 lbs. per square inch. At 150 lbs. per square inch No. IV seems just to touch the maximum velocity obtainable by a nozzle of that taper, while for 200 lbs. per square inch even No. IV may be said to give insufficient expansion.

As a guide to the design of the most efficient nozzle, *i.e.* the one that will develop the greatest kinetic energy in the jet per pound of steam consumed, the results of the present experiments may be summarised as follows:—

Up to a boiler-pressure of about 80 lbs. per square inch, and for discharge into atmospheric pressure, the most efficient form is an orifice in a thin plate. For higher boiler-pressures an expanding conical nozzle with an inner edge only very slightly rounded should be used. The taper should not be very different from 1 in 12, and the proper ratio of greatest and least diameters is given, according to the present results, in the following Table:—

Steam-pressure in lbs. per square inch	80	100	140	160–200
Ratio of diameters	1·26	1·26 to 1·33	1·36	1·36

The bearing of the above results on the thermo-hydrodynamic equation of Weisbach is not very direct. The part played by friction in these nozzles is very great, and can only be allowed for in the equations by the introduction of artificial coefficients, and these the Author has not thought worth calculating, especially as it seems doubtful if hydrodynamic equations are applicable to gases. Hydrodynamics is based on the assumption of a perfectly homogeneous fluid, but a gas, and still less a vapour carrying particles of water in suspension, does not satisfy this condition. To be sensibly homogeneous, the infinitesimal element would have to be large—even comparable with the dimensions of the nozzle itself. It appears, therefore, that the mathematical solution of the question is to be sought rather on the lines of the kinetic theory than on those of hydrodynamics. Some of the peculiarities in the curves shown in this Paper can be explained in a general way by abandoning the idea of stream-lines and considering the reflection of molecules impinging on portions of the inlet surface.

With a convergent inlet the tendency would be to reduce the velocity and increase the density of the stream immediately on the high-pressure side of the narrowest section, thus increasing the total discharge, but diminishing the reaction. In this way one of the most striking features of the present results would be accounted for.

The experiments were carried out in the Engineering Laboratory of Cambridge University in the winter of 1897–98. The Author has to thank Professor Ewing, F.R.S., for numerous suggestions during the course of the experiments.

The Paper is accompanied by complete tabular records of the results of the experiments, and a bibliography which is reproduced in the Appendix, and by thirteen drawings, from which the Figures in the text have been prepared.

[APPENDIX.

APPENDIX.

The following is a list of all important Papers, &c., that have come to the Author's knowledge, bearing on the subject of the discharge of elastic fluids. The order is approximately chronological.

Young	Phil. Trans., 1800, p. 187.
Lagerbjem	Account by Girard in Annales des Chim. et Phys., xxi., p. 204, 1811–15.
Schmidt	Poggendorf's Annalen, ii., 1824.
Banks	Memoirs of the Lit. and Phil. Soc., Manchester, vol. i., p. 389.
D'Aubuisson . . .	Annales des Mines, 1e serie, t. xiii., 1826.
Koch and Buff . .	Poggendorf's Annalen, 1836–37.
Saint - Venant and Wantzel	Journal de l'Ecole Polytechnique, 1838.
„ „ „	Comptes Rendus, 1839–45.
Trémery	Annales des Mines, 1841, t. xx., p. 343.
Becqueret et Poucelet	Comptes Rendus, vol. xxi., 1845.
Graham	Phil. Trans., 1846–49–63.
Froude	Proc. Inst. C.E., vol. vi., 1847.
Joule and Thomson .	Proc. R.S.L., vol. viii., 1856.
Weisbach	Civil ingenieur, Band v., 1859; Band xii. 1866.
Joule	Memoirs of the Lit. and Phil. Soc., Manchester, 3 series, vol. l., p. 102.
M. Herrmann . . .	Zeitschrift Verein Deutscher Ingenieure, 1860, p. 34.
Minary et Résal . .	Annales des Mines, 5e serie, t. xix., 1861.
„ „ . .	Civil ingenieur, 1862.
R. D. Napier . . .	"On the Velocity of Steam," F. and U. Spon, 1866.
„ . .	Engineering, vol. xvii., pp. 404, 418.
„ . . .	Engineer, vol. xxiii., Jan. 4th and 25th, 1867.
Rankine	Engineer, Nov. and Dec., 1869.
Kolster	Zeitschrift Verein Deutscher Ingenieure, band xi., p. 345, 1867; band xii., p. 97, 1868.
G. Wilson	Engineering, 1872.
Siemens	Engineering, 1873.
Zeuner	Civil ingenieur, Band xx., 1874.
„	"Technische Thermodynamik."
Fliegner	Civil ingenieur, Band xx., 1874; Band xxiii. 1877.
James Brownlee . .	Trans. Inst. Engineers and Shipbuilders in Scotland, vol. xviii., p. 13, 1874–75.
Grashof	"Theoretische Maschinenlehre," Leipzig, 1875.
A. G. Hirn . . .	Comptes Rendus, 1886.
Osborne Reynolds .	Phil. Mag., March, 1886.
Peabody and Kunhardt	American Society of Mechanical Engineers, vol. x., 1888–89; vol. xi. 1889–90.
Sauvage and Pulin .	Annales des Mines, 9e serie, t. ii., p. 192, 1892.
H. N. Parenty . .	Annales de Chim. et Phys., 7e serie, t. viii., 1896; t. xii., 1897.
W. C. Unwin . . .	Encyclopædia Britannica, 9th ed., article, Hydromechanics.

Full accounts of many of the above Papers will be found in the articles by G. Wilson in *Engineering*, 1872; and in Zeuner's work, "Technische Thermodynamik"; the most concise views of the mathematics of the question will be found in Unwin's article on "Hydromechanics" in the Encyclopædia Britannica, 9th ed.; and in a Paper by Osborne Reynolds in the Philosophical Magazine for March, 1886.

(*Paper No. 3197.*)

"The Adiabatic Expansion of Wet Steam."

By FRANK WILLIAM ARNOLD, Assoc. M. Inst. C.E.

IT is known that the law $p v^{\gamma} = c$ does not hold exactly for the adiabatic expansion of wet steam; the law is, however, nearly true in many cases, and the value of γ depends upon the range of expansion, the initial temperature, and the initial dryness.

In some of the Author's work it was necessary to find the value of γ for steam of various drynesses and temperatures; this was done graphically, using the equation—

$$\log p + \gamma \log v = c.$$

As most of the ranges were of 80° C. an attempt was made to form an expression which should give the value of γ for a range of 80° C., and for any initial dryness and temperature. The expression found will be seen to involve less labour in its application than either the usual equation or a graphical solution, while it gives the results as accurately.

Fig. 1.

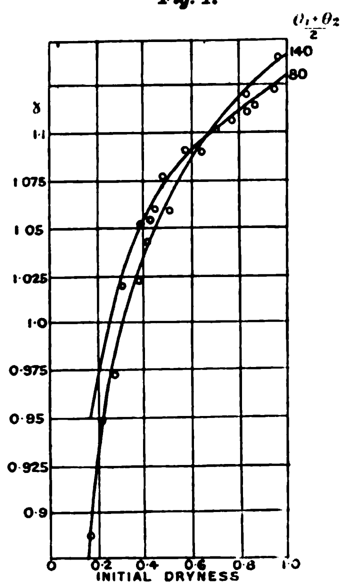


Table I gives the values of γ obtained, correction being made for the volume of water where it affected the results.

For each mean temperature a curve was plotted with the initial drynesses (x_1) as abscissas and the corresponding values of γ as ordinates (*Figs. 1, 2* and *3*), and from these curves the values of γ were read off for initial drynesses of 0·2, 0·3, 0·4 .... 0·9 and 1, and another set of curves (*Fig. 4*) were drawn with the values of

TABLE I.

$\frac{\theta_1 + \theta_2}{2}$	x_1	γ	x_1	γ	x_1	γ	x_1	γ	x_1	γ	x_1	γ	x_1	γ	x_1	γ	x_1	γ
180	0·237	0·91	0·324	0·97	0 36	0·982	0·484	1·04	0·608	1·07	0·866	1·119	0·948	1·127	..	..	..	..
160	0·2	0·91	0·337	0·995	0·478	1·051	0·604	1·081	0·63	1·09	0·8	1·112	0·836	1·121	0·923	1·131	0·953	1·134
140	0·171	0·889	0·228	0·949	0·279	0·973	0·387	1·023	0·413	1 04	0·495	1·059	0·627	1·09	0·818	1·119	0·97	1·138
120	{0·2 {0·94	0·932 1·132	0·253 1·0	0·977 1·115	0·3 ..	0·998 ..	0·371 ..	1·033 ..	0·424 ..	1·053 ..	0·5 ..	1·066 ..	0·596 ..	1·089 ..	0·7 ..	1·103 ..	0·768 ..	1·112 ..
100	{0·131 {0·616	0·886 1·09	0·224 0·689	0 972 1 104	0·273 0·752	1·0 1·112	0·317 0·967	1·015 1·115	0·383 0·968	1·047 1·126	0·41 ..	1·048 ..	0·433 ..	1·06 ..	0·503 ..	1·074 ..	0·592 ..	1·089 ..
80	{0·291 {0·848	1·02 1·114	0·393 0·936	1·052 1·123	0·418 ..	1·06 ..	0·439 ..	1·065 ..	0·504 ..	1·076 ..	0·587 ..	1·089 ..	0·676 ..	1·100 ..	0·762 ..	1·108 ..	0·826 ..	1·112 ..
60	0·17	0·976	0·185	0·983	0·2	0·984	0·344	1·042	0·424	1·064	0·503	1·080	0·580	1·089	0·854	1·115	0·9	1·115
40	{0·134 {0 958	0·958 1·114	0·221 ..	1 007 ..	0·28 ..	1·085 ..	0·353 ..	1·052 ..	0 426 ..	1 068 ..	0·499 ..	1·08 ..	0·569 ..	1·089 ..	0·646 ..	1·095 ..	0·718 ..	1·097 ..

$\frac{\theta_1 + \theta_2}{2}$ as abscissas, and the corresponding values of γ as ordinates, for each initial dryness.

Between the useful extreme limits of temperature (220° C. and

Fig. 2.

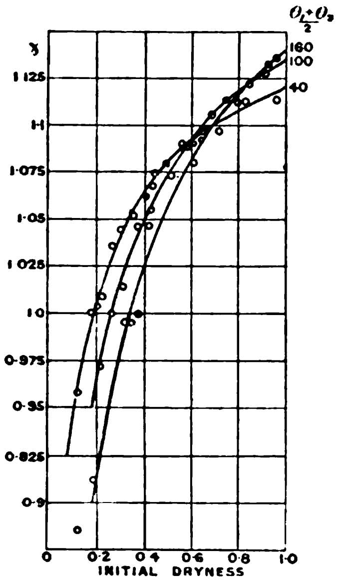
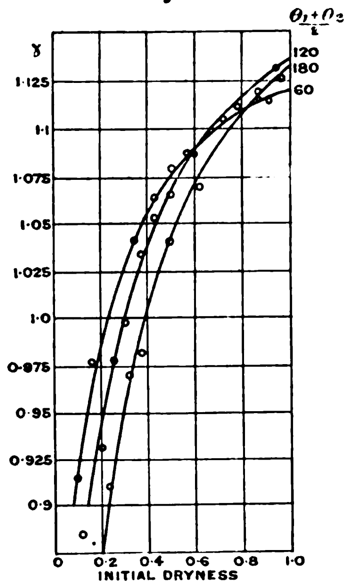


Fig. 3.



40° C.) the mean straight lines of the curves in *Fig. 4* converge to a point (−70, 1·125). The lines were drawn, and in the second column of Table II are given the values of the tangents of the

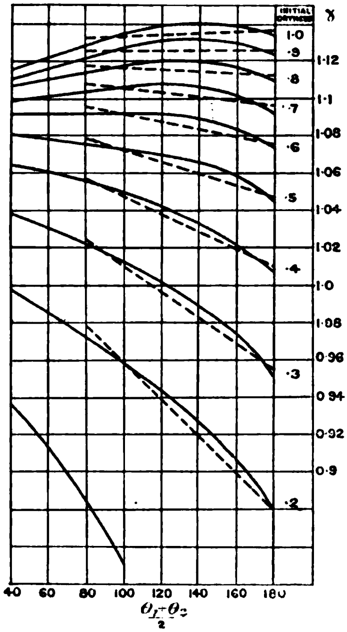
TABLE II.

Initial Dryness x_1.	Estimated Tangent of Angle.	$\frac{0\cdot0323}{x_1^2} - \frac{0\cdot449}{x_1} + 0\cdot459$.
1	0·05	0·042
0·9	0·00	0·000
0·8	−0·05	−0·052
0·7	−0·12	−0·116
0·6	−0·19	−0·200
0·5	−0·31	−0·310
0·4	−0·46	−0·462
0·3	−0·67	−0·679
0·2	−0·97	−0·978

Fig. 6 shows the points in column 2 and the curve from column 3 plotted with x_1.

angles which they made with the line $\gamma = 1 \cdot 125$. In the third column are given the values of the expression—

Fig. 4.



$$\frac{0 \cdot 0323}{x_1^2} - \frac{0 \cdot 449}{x_1} + 0 \cdot 459 \quad . \quad (1)$$

which very nearly agree with the numbers found, if x_1 lies between $0 \cdot 2$ and 1.

Utilizing expression (1), the following expression is obtained—

$$\left.\begin{array}{l} \gamma = 1 \cdot 125 + \dfrac{\theta_1 + \theta_2 + 140}{2{,}000} \\ \left(\dfrac{0 \cdot 0323}{x_1^2} - \dfrac{0 \cdot 449}{x_1} + 0 \cdot 459\right) \end{array}\right\} \quad (2)$$

which holds within 1 per cent. if $\frac{\theta_1 + \theta_2}{2}$ lies between 180° and 80° C. and the initial dryness x_1 is greater than $0 \cdot 2$.

Table III gives the values of γ from equation (2) for a few cases—

TABLE III.

Range of Temperature.	$x_1 = 1 \cdot 0$	$x_1 = 0 \cdot 8$	$x_1 = 0 \cdot 6$	$x_1 = 0 \cdot 4$	$x_1 = 0 \cdot 2$
200° C.—120° C. . . .	1·135	1·113	1·079	1·009	0·900
160° C.—80° C.	1·133	1·115	1·087	1·037	0·939

An equation giving the average value of γ for any range of temperature in terms of the initial dryness is—

$$\gamma = 0 \cdot 77 + 0 \cdot 98 \, x_1 \, (1 - x_1 + 0 \cdot 37 \, x_1^2) \quad . \quad . \quad (3)$$

This curve, together with the average values of γ obtained from Table V, is plotted in *Fig. 5*, and Table IV gives the values of γ from this equation.

Formulas (2) and (3) have been found very useful for quickly obtaining the value of γ.

TABLE IV.

$x_1 = 1·0$	$x_1 = 0·9$	$x_1 = 0·8$	$x_1 = 0·7$	$x_1 = 0·6$	$x_1 = 0·5$	$x_1 = 0·4$	$x_1 = 0·3$	$x_1 = 0·2$
1·133	1·123	1·113	1·100	1·08	1·06	1·03	0·99	0·93

No attempt has been made to give an equation of the exact

Fig. 5.

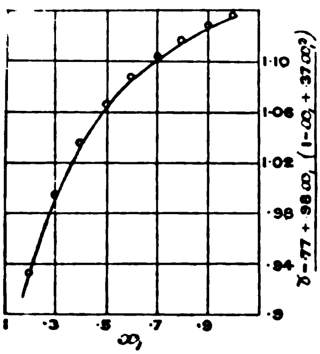
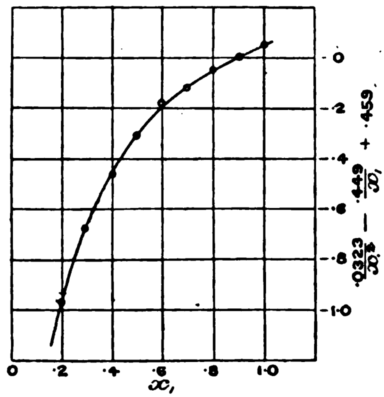


Fig. 6.



variation of γ; taking into account all the intricacies, such an equation would be more of mathematical than practical interest.

TABLE V.

$\frac{\theta_1 + \theta_2}{2}$	$x_1=0·2$	$x_1=0·3$	$x_1=0·4$	$x_1=0·5$	$x_1=0·6$	$x_1=0·7$	$x_1=0·8$	$x_1=0·9$	$x_1=1$
180	0·880	0·951	1·006	1·043	1·073	1·093	1·108	1·122	1·133
160	0·907	0·974	1·021	1·057	1·083	1·100	1·115	1·128	1·139
140	0·927	0·989	1·033	1·065	1·089	1·105	1·119	1·129	1·140
120	0·944	1·001	1·042	1·069	1·091	1·106	1·119	1·129	1·138
100	0·959	1·012	1·049	1·072	1·091	1·106	1·117	1·126	1·134
80	0·973	1·021	1·056	1·075	1·091	1·104	1·113	1·120	1·128
..	0·932	0·991	1·034	1·063	1·086	1·102	1·115	1·126	1·135

The Paper is accompanied by five drawings, from which the Figures in the text have been prepared.

"The Functions of the Engineer."[1]

By Sir William Henry Preece, K.C.B., F.R.S.,
Past-President Inst. C.E.

The success of the modern engineer is due to the fact that he has buried in the depths of oblivion the much-vaunted empirical rule of thumb, and that he has elevated to the heights of science the observations of exact practice and the exercise of pure reason. The principle of doubt, which is the root of all scientific inquiry, forces him to consider every phase of weakness in the materials that he employs in his structures, to examine every possible cause of error in his designs, to anticipate every source of failure in his work. The principle of faith, which is the outcome of the growth of his experience, must be continually illuminated by the light of progress, and controlled by the patient development and consideration of the too-long-hidden laws of Nature. The engineer must maintain his acquaintance with ever-growing science so as to be able to fulfil promptly and accurately his duty, which is the application of the great principle of energy and the utilization of the marvellous properties of matter to the wants, comfort, and happiness of man.

In considering the functions of the engineer we have to consider his *practice* and his *making*.

His practice—what has he got to do? The practice of engineering can be divided into three branches: Civil, Military, and Naval.

The term civil was originally introduced to distinguish the practical man of peace from the practical man of war. Engineering applied to our wants and comforts is a very different thing to that applied to the destruction of our foes or to protect ourselves from their wish to destroy us. War is waged both on land and sea, and as the conditions involved in attack and defence in modern times have become so totally different in these two cases,

[1] An address delivered to the Glasgow Association of Students of the Institution, on the 8th February, 1900.

the term military has been gradually confined to the operations of our army on land, while the term naval is applicable to the warlike operations of our fleets. England owes her present position as the centre of a great empire to her naval supremacy, and she has acquired this supremacy as much by the inventive, constructive, and maintaining powers of her working engineers as by the mighty deeds of her fearless fighting sailors.

Civil engineering aids us not only to build that haven of rest and comfort that we call HOME, but to surround it with the elements of health—pure air, pure water, pure food, pure light. If we aggregate together in towns or scatter ourselves in country districts it supplies us with all possible means of transport by road, river, and rail, and of means of intercommunication by post, telegraph and telephone. These means of annihilating time and space are not only inter-urban in our own country but international in our continents, and in a wider sense imperial, cosmical, and universal, over the whole earth. The world is knit in one connected whole by wire. We know to-day from that triumph of art, science, and culture—the intelligent and free British daily public press—the history of nearly all that took place yesterday over the whole globe.

The engineer fears not the infinitely great, for the stars in their courses aid him to survey the land and to cross the deep with safety. He spurns not the infinitely little, for the molecules in their mutual actions and reactions supply him with those metals and those elements of purity and strength which give him the means to resist the forces of Nature so as to span the broad channel, laugh at the foaming river, build the palace of glass at Sydenham, cover acres of ground so as to display this year in Paris the goods, manufactures, and works of art, industry and utility of the whole world.

The engineer utilizes matter wherever it can be found; he delves into the crust of the earth for ores and minerals which give him wealth, currency, protection and strength; he dives into the sea to survey the bottom as a bed for his cables, and to see that he has secured proper foundations for his moles, piers and breakwaters; he explores the surface of the earth for articles of necessity, of use and of luxury. He irrigates the land, to prepare it for the growth of pure and wholesome food, for the supply of cheering and sustaining drinks, for the maintenance of the stores on the shelves of the doctor, and for those articles of pure clothing that add so much to the comfort, cleanliness and health of man. He utilizes for his purposes the great principle

of energy so as to transform it at his will into its various forms of heat, light, electricity, sound, chemism and material motion. By these agencies he transforms crude matter into its various elements, compounds and states, so as to secure permanence, strength and value.

Life is not free from his grasp. He has developed the Empire of Bacteria and has encouraged the minute microbe in countless armies—to liquefy and purify our sewage, and to become the scavenger of our homes and our cities. He has by defensive measures freed the soil and the river from those ruthless bacterial enemies who invade our frames and bring disease and death in their train.

Engineering is divided into various sections, many of them having their own institutions and their own publications.

The definition of a Civil Engineer, as given in the Charter of the Institution, is very comprehensive. This Institution is "a Society for the general advancement of Mechanical Science, and more particularly for promoting the acquisition of that species of knowledge which constitutes the profession of a Civil Engineer, being the art of directing the Great Sources of Power in Nature for the use and convenience of man, as the means of production and of traffic in states both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation and docks, for internal intercourse and exchange, and in the construction of ports, harbours, moles, breakwaters and lighthouses, and in the art of navigation by artificial power for the purposes of commerce, and in the construction and adaptation of machinery, and in the drainage of cities and towns."

It is difficult to classify the sections of Engineers into any logical order; but I have attempted in the following Table to arrange methodically the various branches upon the same principle as we draw up a genealogical tree, for every branch emanates by direct descent from the one root, Engineering, which is Applied Science.

The growth of invention in early ages was very slow. Man sheltered himself in caves. How long did it take him to devise a tent, or a hut, or a house? How long to protect himself with clothing? How long to construct weapons of offence and defence, not only to protect himself from wild beasts and from his neighbours, but to secure for himself food and raiment. The first protection from weather was probably the skins of the animals he hunted, killed and ate, and the first art acquired—the making of leather. How long did it take him to obtain a knowledge of the

ENGINEERING.

- CIVIL.
  - *Domestic.*
    - Bells and Signals.
    - Buildings (Architecture).
    - Drainage.
    - Lifts.
    - Lighting.
    - Ventilation.
    - Warming.
    - Water-supply.
  - *Municipal.*
    - Electrical Energy.
    - Gas.
    - Housing the Working Classes.
    - Hydraulic Power.
    - Hygiene.
    - Markets.
    - Overcrowding.
    - Parks and Recreation Grounds.
    - Public Buildings.
    - Public Lighting.
    - Refuse-destruction.
    - Sewerage and Drainage.
    - Slaughter-houses.
    - Smoke-prevention.
    - Streets.
    - Tramways.
  - *Inter-Urban.*
    - Bicycles.
    - Canals.
    - Motors.
    - Railways.
    - River Navigation.
    - Roads.
    - Telegraphs.
    - Telephones.
    - Surveying.
  - *National.*
    - Breakwaters.
    - Ceramics.
    - Chemical Industries.
    - Coinage.
    - Construction of Machinery and Engines.
    - Docks.
    - Harbours.
    - Irrigation and Agriculture.
    - Lighthouses.
    - Management of Estates.
    - Manufacturing Processes.
    - Metallurgy.
    - Mining and Quarrying.
    - Refrigeration.
    - Signal Stations.
    - Trigonometrical Survey.
  - *International.*
    - Connection of National Surveys.
    - Lighthouses.
    - Posts (Letter Carriage).
    - Steam Navigation.
    - Submarine Telegraphy.
  - *Cosmical (or Universal).*
    - Astronomical Mensuration.
    - Geodesy.
    - Hydrography.
    - Manufactures.
- MILITARY.
  - Fortification.
  - Artillery and Explosives.
  - Surveying and Reconnaissance.
  - Submarine Mining.
  - Signalling and Telegraphy.
  - Barracks Construction.
  - Traction. Road, Railway making.
  - Search-lights.
  - Ballooning.
- NAVAL.
  - Artillery. Gun Mountings. Explosives.
  - Ship-building.
  - Marine Engineering.
  - Hydrography.
  - Application of Steam, Hydraulics and Electricity to the auxiliary machinery of Ships.
  - Torpedoes. Submarine Mining.

use of fire, and of the means of producing it artificially, so as to cook his food and to bake the plastic clay into pots and pans for drinking and eating purposes?

We have no record of these early stages of the evolution of the human being. The first known picture depicts him as a hunter. Ages elapsed before the conception of a record "engraved upon the rock forever" seems to have occurred to him, and though stone, papyrus, clay, skin and wax, gave him material upon which he could record in elementary pictures his victories, his virtues, and his commands, many centuries passed before the greatest invention the world has ever acquired—the alphabet—occurred to some smart Phœnician, probably in the land of Egypt, where picture-writing, hieroglyphy, had reached its acme. It has taken 3,000 years to mature this invention. The alphabet we use to-day is a direct descendant of that first Phœnician attempt to indicate the elementary sounds of speech by letters. But what a change has occurred since the next great invention in this direction—printing! The brain is now excited by the publication of every new fact extracted from Nature's storehouse. Inventions spring up like mushrooms. They are published by the press to the whole world at once. Innumerable minds of all nations are thus set to work to utilize, develop and improve them. Advance is rapid and progress proceeds at a compound interest rate. I said it took 3,000 years to mature the alphabet. It has taken 450 years to perfect printing, but 60 years in our days have matured telegraphy and photography, and only 60 months have been sufficient to apply Röntgen rays to assist the physician to apply his gentle art to restore to health the maimed and wounded. Such is the advantage of publicity!

Why such marvellous constructive skill and scientific progress should have been developed on the banks of the Euphrates and the Nile on the old, and in Mexico and Peru on the new continent, so early in the history of the world, is a mystery of the development of the mind that remains to be satisfactorily explained as much as the persistent conservatism of the negro and the gipsy of the present day. The wicker hut depicted on Egyptian bas-reliefs 3,000 years ago is the same dwelling place of the same race in the present day!

The luxurious, roomy, and well-warmed southern villa of their Roman conquerors failed to commend itself permanently to the mind of the unrefined ancient Briton. Nevertheless the Roman left us the arch, showed us how to build a bridge, and left us his straight and admirable road. The words arch, pont and street,

remain in our languages historical memorials of those early colonists.

The rapid progress of modern engineering is phenomenal. Practice grows by leaps and bounds. Take any form of energy and examine its utilization in any field of industry. Take only one instance of the application of electricity. See how it comes to the aid of the sailor! It controls the rudder, it ventilates the interior and the living space of the ship, it forces the draught and assists the raising of steam, it revolves the turrets, it trains and controls the guns, it handles the ammunition, it purifies the drinking water, it lights up the ship internally, it enables the captain to sweep the horizon with the brilliant rays of the search-light, and to communicate with his tender, or with his commanding officer across space independent of weather, night, season, fog or rain. It would lengthen this address too much to illustrate this point further. Light, sound, heat, chemism and mechanics have been equally active in the service of man, and have helped to specialize in many directions the functions of the engineer.

The Making of the Engineer.—It is idle to ignore the fact that the modern engineer is the outcome of high-class and long-sustained education, either imparted or self-acquired. Education means generally the training of the intellectual, moral, and physical faculties of youth, but the education of the engineer never ceases as long as he remains in active practice. I am still in school, and rarely fail to acquire some new fact each day of my life. The first foundation is clearly a broad, solid, general education, not specialized in any way until the pupil has reached the stage when he can work and think for himself. But from the very earliest years—in fact, from infancy—I advocate the cultivation of the powers of observation, a systematic training of the memory, and an encouragement of the exercise of thought. This is, in reality, the scientific method. Many people advocate the early teaching of science, but I do not. I advocate the collection and naming of plants, the love of animals and knowledge of their habits, the observation and explanation of the daily occurrences in the house, the air and the ground. The fire, a candle, the teapot, cooking, blacking boots, the dewdrop, clouds, rain, wind and storm, the ebb and flow of the tide, the performances of tops and bicycles, familiarly explained, excite a love of Nature and of Science, and train the mind to observe, to think and to remember. Cramming the young mind with ill-digested text-book science, illustrated by experiments that generally fail, excites ridicule—the common accompaniment of ignorance.

The engineer must be a scientific man. Science deals with the facts of Nature, their laws and their theory. The engineer applies this knowledge to the uses of mankind. His practice means the correct design and due execution of works. The present President of the British Association, in his inaugural address delivered at Dover, drew no distinction between Natural Knowledge (Science) and Applied Science (Engineering). His illustrations to glorify the former were drawn from the triumphs of the latter. Sciences are *experimental*, such as chemistry, mechanics, and physics, and *observational*, such as botany, zoology, geology, geography, astronomy, biology, &c. They are very numerous, and, as engineering is only another term for applied science, it is clear that an engineer would waste his time in acquiring abstruse sciences that would be of no subsequent use to him. He must confine himself to those branches of Science which will be of service to him in his future career, so as to enable him to apply them to living, industry, and commerce. Mathematics, the shorthand of thought and the purest form of logic, experiment, the handmaid of observation, measurement, the instigator of accuracy and precision, and reasoning, the organ of common sense, are the tools that shape his store of knowledge which memory brings to his help when he has to practise what he has learnt. The boy who has passed well through the ordinary curriculum of school, and proceeds thence into a University, from which he emerges as a young man not only well imbued with the refining influences of literature and art, but with a well-earned degree of science, is fully prepared to commence his engineering training and to enter the workshop or the drawing-office, where alone he can acquire that combination of knowledge and skill, and that training of the brain and the hand for mutual aid which is called Technical Education.

The Institution of Civil Engineers will now admit into their body only those who can produce the certificate of such an educational career as I have indicated above, or who can pass an examination which will give evidence of the possession of similar qualifications. A scientific man can become an engineer only when he has become an expert through practice and experience.

It is not a question between science and practice; it is a question between science and rule of thumb. Practice is always there, but rule of thumb means rule of error, until by repeated failures rule of thumb becomes rule of right, which means the victory of organised common sense. Organised common sense is a very good term for science. Scientific men talk nonsense when they observe

differences between science and practice, and so-called practical men act foolishly when they ignore science, and assert that an ounce of practice is worth a ton of theory. Practice based on true science means immediate success and economy; practice based on rule of thumb means error, delay and excess of estimates. The engineer cannot neglect the laws of nature, any more than the scientific man can ignore the success of practice. The science of the Chair has, however, often been obsolete or behind the day. The professor is not sufficiently in touch with the industrial and economical interests of the country. It happens that in my own special branch of the profession practice has always been in advance of theory. The progress of telegraphy and telephony owes nothing to the abstract scientific man. The fundamental principles and natural facts that underlie the practice of electrical engineering are the teachings of actual experience, and not the results of laboratory research or professorial teaching. The science is, however, now established, and those who are academic students have the advantage of acquiring a knowledge of facts and principles in the class-room before they commence their practical career. Their path is thus much cleared and their progress expedited. They start well equipped mentally to grasp and comprehend the art of their profession.

Smeaton, Watt, Telford, Stephenson, Fairbairn, Whitworth, and all our early engineers had to acquire their own natural knowledge by their own individual investigations. They had to seek out and determine first principles for themselves. All that is now changed. The science of to-day is the science of the Victorian era. The engineer is not now required to research as much as his predecessors. There are now physical laboratories where it can be done for him, but this must not tempt him to lessen his enthusiasm in verifying the facts of nature by experiment. Doubt must always be transformed to faith.

The civil engineer of eminence has not only to know thoroughly the science, but to conduct the practical operations of his profession. The lives of human beings are entrusted to his designs. People have faith in the safety of his ships, long tunnels, bridges and railway trains. He is called upon to advise on policy, to deal with commercial management, to act as arbitrator or judge in many important intricate judicial cases, and to appear in courts of law and committee rooms of Parliament as an expert witness. The mental qualities of the engineer must therefore be of the very highest order. His scientific training and his world-wide practice have broadened his views and enlarged his mind. Above all his

character must be above all reproach. The honour of the engineer is the honour of his profession. The Lord Chief Justice's Bill was welcomed by every member of the Institution of Civil Engineers. The evil it is desired to suppress is very great and very wide, but it is not the characteristic of the engineer.

Let me in conclusion impress on you the antiquity and the universality of the functions of the engineer. Tubal-Cain was an instructor of every artificer in brass and iron, and this before the flood. The very earliest remains of Egyptian, Babylonian, and Assyrian temples and monuments, indicate a wonderful knowledge of the strength of materials. The Cloaca Maxima of the early Latin King Tarquinius Priscus exists still, though built 2,600 years ago. In the track of war and diplomacy, in the earliest days of history, went trade and commerce. The general became the engineer. Western Asia was covered with roads not only to facilitate the transport of troops and chariots but to assist the merchant in the distribution of his wares. Intercourse of all kinds has always been the outcome of civilization. The balance of power falls to the strong. In days of old it was to the strong physically. In modern days it is more to the strong mentally and financially. The greatest political gift that mind can give to man, the greatest security for peace and comfort, is the ability to wield the great powers of nature so as to destroy human life with the greatest rapidity and at the greatest distance. An overpowering fleet and an efficient army are our insurance for security at home. There is not a habitable spot on the face of the earth that does not bear traces of the presence of the engineer. He is the great civiliser. He not only immediately follows, but he sometimes even precedes the military conqueror. He distributes peace and good-will without the accompaniments of fire, blood and famine. Mr. Cecil Rhodes is opening up Africa with the "wonder-working wire." Khartum has been brought within 70 hours of Cairo by train, and ere long, when peace is restored in that self-disturbed country South Africa, Cairo and Cape Town will be in direct and immediate communication by telegraph, and eventually by rail.

The engineer is not only a benefactor to his race, but he is a necessity of the age.

(*Students' Paper No. 435.*)

"The Construction of the Elan Aqueduct: Rhayader to Dolau."[1]

By Herbert Lapworth, Stud. Inst. C.E.

The Elan Aqueduct forms part of the new scheme which has been designed by Mr. James Mansergh, Vice-President Inst. C.E., to supply the city of Birmingham with water from Wales. This aqueduct, which is to convey the waters of the rivers Elan and Claerwen from Radnorshire to Birmingham, is now in construction under several contracts, the most westerly of which forms the subject of the present communication.

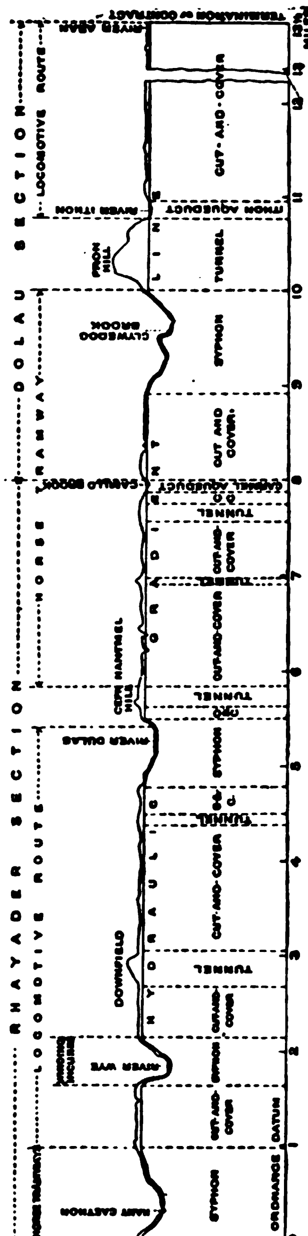
This contract commences at about 1½ mile west of the town of Rhayader, in Radnorshire, and a little more than 3 miles east of the proposed intake at the Caban Côch reservoir. It extends over a length of 13½ miles, and terminates at the Dolau railway station, in the same county, *Fig. 1.* The greater portion of the length consists of cut-and-cover work, practically contouring the hillsides, but falling throughout at a gradient of 1 in 4,000. There are a few short tunnels at the same gradient. Where the aqueduct crosses valleys of great length and depth, pipes are substituted for the cut-and-cover work, with a hydraulic gradient of 1 in 1,760. Dingles and narrow river valleys are spanned by aqueduct bridges, the conduit being carried over on arches.

The contract was let in May 1896 to Messrs. John Aird and Sons, London. From the commencement the work was divided into two sections, a western portion 8 miles long, and an eastern portion about 5½ miles in length. Each section, with its own plant, was worked more or less independently throughout.

Work was begun in June 1896. At the outset a wagon road was laid down and connections were formed at Rhayader and Dolau between the main railways and the works. The junction at the west end was made at about ½ mile south of Rhayader

[1] This Paper was read and discussed at a Students' Meeting on the 10th March, 1899.

Fig. 1.



Horizontal scale, 1 inch = 2 miles. Vertical scale, 1 inch = 1,000 feet.

Longitudinal Section of Contract Length.

Station, on a branch line belonging to the Birmingham Corporation, and running from the Cambrian Main Line to the Elan Valley Works. From this junction to the Rhayader depot a winding incline was constructed, and from the top of the grade a locomotive route, 4 feet 8½ inches gauge, for conveying plant and materials along the track, ran eastward, parallel to the centre line of the aqueduct, and terminated at the foot of Cefn Nantmel Hill, at a distance of 4½ miles from Rhayader.

On the Dolau section, a corresponding wagon road was laid down in connection with the London and North Western Railway at Dolau Station, whence a full gauge locomotive route was carried eastwards along the track to the foot of Fron Hill, at a distance of about 3 miles from Dolau Station. All plant and materials could now be conveyed at once to their required destinations, throughout a total length of 7½ miles, namely, 4½ miles from the Rhayader end of the track, and 3 miles from the Dolau end; but a central section of some 6 miles was still unprovided for. This gap, however, was soon filled in. From the termination of the western locomotive route a horse-road, 2 feet 8½ inches gauge, was formed, extending through the intermediate section to the

western side of the Fron Hill. All goods required along this intermediate portion were delivered first at Pen-y-bont Station, and then conveyed along the high road, either by carts or by traction engines, and were transferred to the narrow-gauge wagons at the various points where connections were formed between the horse road and the high road, namely, at Fron, Gwystre, and Hirfron, distant from Pen-y-bont Station, 1 mile, 2 miles, and 3 miles respectively. Two 10-ton traction engines were in use, each capable of making four journeys per night from Pen-y-bont to Hirfron. Pipes were carried in special four-wheeled "whims." The locomotive routes were of the full 4 feet 8½ inches gauge, with 56-lb. rails spiked to the sleepers, which were "boxed-up" with material excavated from the trenches. The inner rail ran at an average distance of about 5 feet from the side of the trench.

The width of land allowed to the contractor was 66 feet, and at a distance of 33 feet from the centre line of the aqueduct, and on each side of it, fences were erected in advance of all work. In constructing the wagon-road, the high roads and lanes were crossed either underneath or on level crossings. In the former case the metalling of the road overhead was carried by a timber bridge. Temporary timber bridges were built also to carry the wagon roads over the River Wye and other streams. The slopes of the Wye Valley were found to be too steep for a locomotive route. Winding inclines were therefore laid down on both sides of the valley. A gang of about eighteen men was usually employed on each section, to form the wagon road, and was followed closely by a plate-laying gang of about twelve men.

The Rhayader depot was situated between ¼ mile and ½ mile south of Rhayader, adjacent to the aqueduct and at the head of the incline already referred to, which connected the main line with the works. The depot covered an area of about 5 acres, and consisted of a cement storage and cooling shed, a saw-mill and winding-engine shed, shops for masons, fitters, blacksmiths and carpenters, two stone saws, and a stone rubbing machine, general stores, a small cement-testing shed, a locomotive shed, and a few temporary dwelling huts. Ground not occupied by buildings was utilized as a depot for siphon pipes, brick, iron-work, and other materials. The buildings in the Rhayader depot were in use for 2 years. They were taken down in July, 1898, previous to the removal of the locomotive route, most of the work along this line being completed. The remainder of the work on the contract to the eastward was carried out from the depots on the Pen-y-bont connection on the Dolau Section.

The main depot for the Dolau Section was situated on a piece of ground adjoining Dolau Station on the London and North Western Railway. In addition to these chief depots, three minor depots were established at the termination of the western locomotive route at the Hirfron connection, and in the yard of the Pen-y-bont Railway Station; a cement-cooling-shed was also erected at Rhyd Llyn, about 1 mile west of Dolau.

The supply of "blue" stone facing, throughout the whole of the contract, was limited to two sources, Cerig Gwynion and Knighton. Stone for crushing purposes was obtained from Cerig-Gwynion, Carmel and Dolau. The freestone for copings, string courses, etc., was supplied mainly from Cefn, Ruabon, but a considerable quantity was obtained from Darley Dale, Derbyshire, and Grinshill, Salop.

The majority of the cuttings on the contract were through hard shales and flags belonging to the Silurian and Ordovician systems. These shales were overlaid by glacial boulder clay, often of great thickness, in one case as much as 30 feet. In "bottoms" or depressions, and near water courses, the clay was often found to be thoroughly water-logged, and in the cut-and-cover work this caused great difficulty in bricklaying.

The operations required for the permanent work can be grouped under four heads, namely:—

1. Pipe-laying.
2. Cut-and-cover work.
3. Tunnelling.
4. Building of aqueduct bridges.

Pipe-laying.—The siphons were designed for an ultimate number of six lines of pipes 42·12 inches in diameter, but on the contract under description only two were laid. The pipes are 1 inch thick, cast in 12-foot lengths, each pipe weighing about 2½ tons. They were cast vertically, socket downwards, and of sufficient length to allow of 4 inches being turned off the spigot end in the lathe. Test bars, cast at the same time as the pipes, 2 inches deep and 1 inch wide, were required to stand, without fracture, and with a maximum deflection of ⅜ inch, a weight of 2,800 lbs. applied at the centre of a 3-foot span. The pipes were coated with Dr. Angus Smith's composition, and, before leaving the works, were tested by oil to an internal pressure of 200 lbs. per square inch. They were cast by the Staveley Coal and Iron Company, at whose works an inspector was appointed by the Birmingham Corporation to superintend the tests, which were made prior to the pipes leaving the premises.

The width of the pipe trench was 10 feet 8 inches. The centres of the pipes being 6 feet apart, a clear space of 6 inches was left between their outside surfaces and the face of the trench. The excavation was carried out by stages. The turf, on removal, was piled up close to the hurdles, for relaying after the trench was filled in. The earth was thrown out to the sides of the trench until the level of the top of the pipes was reached approximately, when the remainder of the excavation was conveyed at once to the nearest spoil bank. The excavating gangs were followed by a few men getting out "joint holes" a few lengths ahead of the pipes already laid. Behind these men came the pipe-lowering gangs and the pipe-jointers, and, last, a few labourers filling in the trench.

The greater portion of the pipe-laying was carried out by means of a travelling timber gantry running on a temporary tramway of 30-lb. flat-bottomed rails, spiked to 9-inch by 3-inch planks on each side of the trench. On the top beam of the gantry a small iron traveller, fitted with rollers so that it could be run into any position along the beam, carried a differential pulley block for raising or lowering the pipes. In timbering the pipe trenches, the outside struts were so spaced along each waling that, on removing the centre strut, a pipe could be lowered between them. Through this gap the pipe was gently lowered, and, by running the gantry along, was moved into place. The bottom of the pipe was then packed on both sides with soft earth from the "joint holes," in order to keep it firmly in position during jointing.

At the bottom of the west slope of the River Wye there is a length of about 50 yards of pipes rising at a gradient of about 1 in 2. Here, of course, it was impossible to make use of a travelling gantry. The pipes were lowered into position with the aid of a crab placed higher up the hill, and were "socketed" either by means of shear legs or by a screw fixed to overhead balks. In crossing the River Wye the pipes were laid below the river bed to a depth of about 8 feet. The river waters were cut off from the trench itself by means of coffer-dams and earth-banks, and were carried over the trench in timber shoots. The pipes were lowered from an overhead platform on the bridge timbers by means of a screw. In preparing to run a joint, steel wedges were first driven between the spigot and socket in order to obtain a space of uniform width. This space was then well caulked with hemp, and the wedges were removed, the tightness of the packing keeping the joint true. A "clasp ring" of 1 inch by 1 inch metal was screwed up tightly against the socket, and a luting of clay

was worked round it, a cup being left at the top into which to pour the lead for the joint. A little grease was smeared on the bottom of the cup to act as a flux, and the pipe was ready for jointing. The ladle, heated at a coke fire at the side of the trench, was placed on the trunnions of a saddle resting on the pipe, and was filled from several smaller ladles carried from the melting-pot until there was a sufficient quantity to fill the joint. When the lead had reached its proper temperature—judged by its colour—the joint was run by tipping up the ladle. The clay and the ring were then removed, and the joint was "set up." In "setting up," the lead was caulked round three times with $\frac{3}{16}$-inch, $\frac{1}{4}$-inch, and $\frac{5}{16}$-inch caulking tools in succession. The thickness of lead in the joints was $\frac{5}{8}$ inch.

The average number of men in each pipe-laying gang, including the excavators, was twenty-two. The average number of pipes laid and jointed per week was between forty-seven and fifty-one, or a little over eight pipes per day. The maximum number of pipes laid and jointed in a day was twenty-two, and the best week's work was a total of eighty-six pipes laid and jointed. On the Wye incline, owing to the steepness of the gradient and the consequent danger of rock rolling down, the number of men employed in excavating and pipe-laying was considerably less than usual, thirteen to fifteen only being employed in place of the usual forty on each siphon. Owing to this fact, and also to the length of time taken in continually fixing stages, lowering, etc., the rate of progress was here extremely low, about $4\frac{1}{2}$ months being required to complete a length of 50 yards.

Cut-and-cover Work.—The excavation for the cut-and-cover work was carried out by "stage" work in shallow cuttings, and by travelling cranes in deep excavations. In a few cases, where it was considered economical, the excavation was removed by means of a "Jubilee" gantry. On the horse tramway, cranes were used only for very deep cuttings. In these cases a short length of the full-gauge road was laid down as a crane road on the side of the trench opposite the narrow-gauge line.

The "Jubilee" gantry was a travelling timber structure, erected over the trench, and running on a temporary road, similar to the tramway used in pipe-laying. A long chain was passed over a system of pulleys on the structure, and round a pulley which was fixed to a post at the side of the trench, but at some convenient distance from the gantry. The ends of the chain were fastened to one empty and to one full wheelbarrow. To the centre of this chain one end of a short connecting-piece was fixed, the other

end being attached to a horse, which, by walking either towards or from the gantry, raised a full barrow to an upper platform, and at the same time lowered an empty one to the bottom of the trench. The timber platform jutted over the wagon road at a sufficient elevation to clear the funnels of the locomotives. Two men wheeled the barrows from the top of the hoist to the edge of the platform, emptying them into the wagons on the road below. This method of getting out excavation was used only in cases where the frame of timbering at the level of the wheelers could be dispensed with, and where the ground was fairly easy to excavate —a combination of circumstances, however, rarely met with. Land drains and small streams were carried temporarily across the trench in timber shoots. On long stretches of sloping ground the land drains were intercepted on the uphill side of the trench and were carried across at the shallow ends of the cuttings in a similar manner.

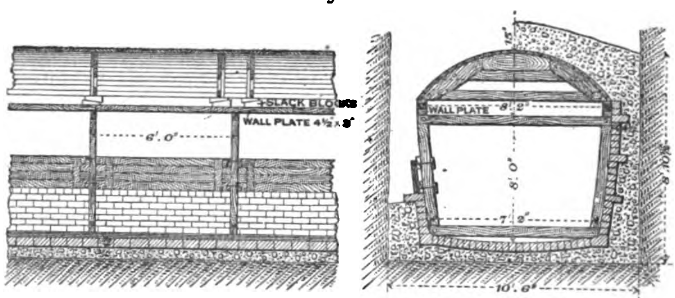
The average number of men employed in each gang excavating the cut-and-cover trench was twenty-four, including timbermen. There were six of these gangs constantly employed on the Rhayader Section. The ground was opened up at points 300 yards or 400 yards apart, and each excavating gang carried on the trench to the commencement of the next excavated section.

The Portland cement on this contract was obtained chiefly from South Wales, but a considerable quantity was supplied by Thames and Medway firms. The cement mortar used on the works was made throughout of sand and cement in the ratio of 3 to 2. The concrete ballast used was of three kinds, viz., (1) broken Cerig Gwynion stone from the Rhayader depot crushers; (2) broken Carmel stone from the crushers in the Carmel Quarry; and (3) broken Dolau stone from the Dolau crushers. Two classes of sand were in use, viz., crushed Cerig Gwynion or Carmel stone, and red sand from the valley of the River Severn. The red sand only was used on the Dolau Section; on the Rhayader Section an attempt was made to use only the crushed sand, but the machines were unable to satisfy the daily demand, and, consequently, the supply was supplemented by the river sand. The crushed sand gave more satisfactory results than the red, being better able to retain water, and giving a superior surface to faced concrete work. The sand crusher was first situated at Downfield, about 1 mile east of Rhayader. It was removed, in April 1898, to Carmel Quarry, as the work at that time lay within the last 4 miles of the Rhayader Section.

Sections of the conduit are shown in *Figs. 2*. It may be defined as a concrete culvert, lined internally on the sides and invert with blue brickwork. The sides are vertical externally, curved internally to arcs of circles, and faced with 4½-inch blue brickwork, with a course of headers every sixth course in height. The invert is a circular arc, lined with 4½-inch blue brickwork. The arch is entirely of concrete, in the same proportions as that in the sides and invert, namely, 6 to 1.

The following was the general method adopted in building up the cut-and-cover work. The trench having been excavated down to its proper level, wooden templates, shaped to the curve of the underside of the invert, were placed transversely, at intervals of 14 feet, along the bottom, and in such a manner as to leave a

Figs. 2.



Scale, 1 inch = 8 feet.

CUT-AND-COVER WORK.

6-inch "garland" on each side of the trench for draining off surplus water during the construction of the invert. Concrete was then placed between the templates, and was shaped to the proper curve for the brickwork. After this concrete had set, the blue-brick invert was laid, together with the corner or invert blocks, on which the facing to the side-walls commences. Frames were then erected along the invert, 6 feet apart, the external boundaries of which formed the required curve of the sides of the internal section. Resting on the invert blocks, and outside the frames, were fixed wooden shutters, 16 inches in height and 12 feet in length. These were supported by means of iron hooks [1] running round the side ribs of the frames, and fitting into staples

[1] These hooks were dispensed with towards the end of the contract owing to their continual disappearance, and the shutters were adjusted from the sides of the trench by short struts.

in the shutters, and were adjusted by wedges so that their external faces were $4\frac{3}{4}$ inches from the inside face of the side walls. The space between the shutters and the sides of the trench was then filled with concrete. In this manner the top of the concrete was brought up to the level of the underside of the first header course, the "garland" mentioned previously being filled at the same time. After a lapse of 48 hours, the minimum time allowed for the setting of the concrete, the shutters were removed, and the brick facing was built up to the lines given by the frames, as high as, and including, the first header course, which rested on the concrete already put in. On this last course the shutters were again set, and the same operation was continued up to the second header course, and so on until the springing of the arch was reached. Grooves were formed in the concrete in order to bind together the successive lifts; and the surface of each layer was washed well before new concrete was deposited.

In the original design for the cut-and-cover section, as already stated, the headers were spaced every sixth course. With full-sized bricks this would mean that after the third header course had been built, only three or four courses of stretchers would be required to complete the sides. As a matter of convenience the brickwork would be built first, and the remaining concrete, with that of the arch, would be put in afterwards, so that, while the arch centres were being fixed, a gap would be left between the facing and the sides of the trench into which dirt might fall from the surface of the ground and from the face of the excavation. The proper cleaning out of such a gap before concreting would be almost an impossibility. For this reason the contractors were permitted to carry up the third lift to within one course below the springing, and to build the topmost course of headers. By this method a very small space only was left, from which dirt could be more easily removed.

When the cut-and-cover work was commenced, wrought-iron frames of tee-bar, bent to the curves of the internal section of the aqueduct, were adopted. These were used for about 6 months, but owing to the difficulty of transporting them, on account of their weight, the length of time required to fix them and the centres for the arch, and also to the nuisance caused by the invert rib preventing water from escaping along the bottom, they were discarded, and were replaced by frames of timber. The bottom ribs of the timber frames were straight, with a 3-inch gap through which water could pass. The top ribs lay about 9 inches below springing level and supported a wall-plate, $4\frac{1}{2}$ inches by 3 inches,

carrying "slack-blocks," which, in turn (when the side-walls were completed), carried the centres for the arch, and enabled them to be adjusted accurately to their proper level. The arch centres were 12 feet in length, were made in three segments for convenience in transportation, and were fixed together in position by ½-inch bolts. In turning the arch round curves (all of which are of 200 feet radius) the centres were made in lengths of 6 feet, curved in plan, and were removed bodily from point to point. The junctions between adjacent lengths of side-walls were formed by "stepping" the brickwork and concrete at the levels of the various lifts. At the end of each length of arch a "stunt-head" was fixed on the top of the centres. This left a V-groove in the concrete to form a key with the succeeding length. For tipping the concrete into the work, wooden hoppers were used. These were fixed under a platform spanning the trench, and to their undersides detachable timber shoots were hung, in order to direct the concrete into the side-walls or into the invert as desired.

The water required for mixing concrete, watering the trenches during "filling in," etc., was brought from the nearest available stream courses, and was pumped through wrought-iron pipes, 2 inches in diameter, laid parallel to the centre line from one end to the other of the various conduit lengths. In passing through bad ground, as already stated, great difficulty was experienced in building the brickwork, in consequence of the water flooding the masonry. This frequently occurred to such an extent that the mortar was washed from between the joints before it had set. This difficulty was overcome largely by building in ½-inch or 1-inch iron pipes at the bottom of the side-walls. These pipes extended from the face of the excavation to the inside of the aqueduct, and allowed the water to escape along the invert. On the completion of the adjoining work these pipes were well caulked with hemp and neat cement. Leaks discovered in the side-walls after the work had set, were almost invariably found to be at the undersides of the header courses; that is, at the levels of the junctions of consecutive concrete lifts, the majority of such leaks occurring at springing level. On the detection of a leak the mortar was raked out from the joint, which was afterwards well caulked with hemp and filled in again with neat cement.

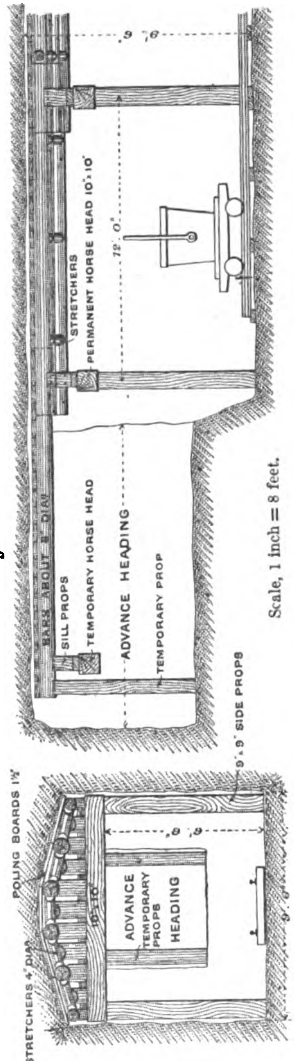
The average number of men in the concreting gangs on the cut-and-cover work was fifteen. The ratio of concreting gangs to excavating gangs, depending mainly on the depth of the trench, was naturally variable, but for an average depth of trench of 15 feet the ratio was about 2 to 3. With five excavating gangs

and three concreting gangs, with the necessary bricklayers and labourers, an average length of 90 linear yards of completed conduit, at an average depth of 15 feet, could be done weekly.

Tunnelling.—When the depth of cutting on the cut-and-cover work exceeded about 30 feet for any considerable length, tunnels were substituted for the open cutting. As a rule the trench was excavated up to the commencement of the tunnel before driving was begun. In one or two cases, however, a shaft, 20 feet long, and having a width equal to that of the trench, was sunk at the commencement, and the driving was carried on from its base. The method of timbering the tunnels is shown in *Figs.* 3. In moderately good ground the tunnels were driven to their full width, leaving a benching, 2 feet 6 inches high, to be removed later. In bad ground a top heading, about 5 feet in width, was driven ahead of the finished timbering in order to allow of the introduction of a temporary sill to support the succeeding crown-bars and their poling-boards, *Figs.* 3. In very firm ground, all timbering was dispensed with.

By far the greater part of the driving was carried out by means of $1\frac{1}{4}$-inch ratchet drills, two drills being used at each face. When the heading was driven at its full width, eleven holes were drilled in the face, each hole being 4 feet 6 inches deep. Gelignite was used exclusively throughout the whole of the tunnel work. The average charge for each hole was about 15 ounces, and

Figs. 3.



Scale, 1 inch = 8 feet.

Method of Timbering Tunnels.

the average total expenditure of gelignite was about 12½ lbs. per linear yard. The excavated material was filled into skips, which were carried on small trolleys running on a tramway of 2 feet gauge, and were run out to the commencement of the tunnel, where they were hauled up to the surface either by steam cranes or steam winches. Two of these trolleys were in use in each heading, two men running with each trolley.

Proper ventilation, and the removal of the gases generated by blasting, were both secured by means of centrifugal fans driven by portable engines, which were employed also for pumping at the ends of the tunnels. The fresh air was delivered through cast-iron pipes, 6 inches in diameter, carried up to within about 50 feet of the face. By this means the products of combustion were forced out towards the end of the tunnel. The tunnels were worked in two 10-hour shifts in the 24 hours at each face, each shift consisting of twelve or thirteen men and one foreman. About 11 linear yards per week was the average progress of tunnel-driving at each face in hard slate throughout the length of the contract. When in full swing, as much as 15 linear yards has been done in 1 week. At the inlet end of the Fron Tunnel a rate of only 8 linear yards per week was accomplished, the difference of progress being due to the relative hardness of the rock beds.

In lining a tunnel, the invert was, in general, first completed throughout the entire length of the tunnel, or portion of tunnel, to be lined, and the side walls were finished before the arch was commenced. The methods adopted in the building of the invert and side-walls were similar to those used in the ordinary cut-and-cover work, but the wooden top ribs of the frames were replaced by those of the original wrought-iron frames already mentioned. The construction of the arch, however, was carried out in a different manner, *Figs. 4*. Eight loose laggings, resting on the curved iron ribs of adjacent frames, were brought up from the springing on each side of the centre line. Concrete was then packed carefully between the laggings and the roof of the tunnel. Two more ordinary laggings, and one special "grooved lagging," were added on each side, and the space between the "grooved laggings" was filled in by special rebated "block laggings." Two "block laggings" were added at a time, and the space between the first lifts of concrete was filled in longitudinally.

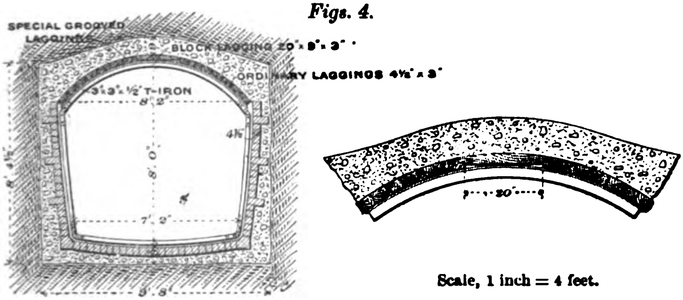
In building the invert and side-walls a gang of fifteen concretors working 10 hours per day, with a gang of six bricklayers and seven labourers working intermittently as required, could

complete weekly a length of 70 linear yards of invert or 40 linear yards of side-walls. On the arch, a gang of fourteen men, working 9 hours per day, completed an average length of 63 linear yards weekly.

Aqueduct bridges.—The two main aqueducts are situated at Bryn-Hyferth and Carmel, crossing the River Ithon and the Camllo Brook respectively. The former bridge consists of twenty-two segmental blue-brick arches faced with freestone, each having a span of 30 feet and a rise of 5 feet. There are six rings of brickwork, 14 feet in width, in each arch. The conduit is carried over the river on an eight-ring arch of 60 feet span. At Carmel there are eleven 30-foot arches and a steel tube, 8 feet 6 inches in diameter, which replaced the conduit over an occupation road.

The stonework on the Ithon aqueduct was set with two 3-ton

Figs. 4.



Scale, 1 inch = 8 feet.

Scale, 1 inch = 4 feet.

CONSTRUCTION OF TUNNEL-ARCH.

travelling steam cranes. Seven centres only were used for turning the twenty-two arches, about 6 months being spent in the operation. The centres were struck a fortnight after keying, except on the river arch, where they were left for a month. About thirty-six men were usually employed on this bridge. The total number of men employed throughout the contract averaged 900 to 1,000. As the works traversed a sparsely populated district, the accommodation in neighbouring villages and farms was insufficient for the number of labourers employed on the aqueduct; temporary wooden huts were therefore built by the contractors for this purpose on suitable sites conveniently near the works. Owing to the work progressing at a more or less rapid rate, and consequently extending to inconvenient distances from buildings already erected, the huts were taken down after a time and removed to

more convenient situations. For ease in transport, and in order to increase the rapidity of re-erection, the sides of the huts were constructed in the form of large panels. Earth closets were provided for each hut. Trains for the workmen, from both Rhayader and Dolau, were run each morning along the locomotives routes, returning in the evening after the day's work.

The time allowed for the completion of the contract, from the date of commencement, is 4 years, but it is expected that little will remain to be done at the end of the year 1899, *i.e.*, about 3½ years from the time at which the work was started.

The Author is indebted to Mr. James Mansergh, Vice-President Inst. C.E., for permission to make this communication; to Mr. W. A. Legg, M. Inst. C.E., the Resident Engineer, under whom the Author acted as Assistant, for providing facilities for the work, and for much valuable information; and to the representatives of Messrs. John Aird and Sons for supplying figures and drawings.

The Paper is accompanied by a map and drawings, from a selection of which the Figures in the text have been prepared.

(*Students' Paper No. 452.*)

"The Construction of the Simplon Tunnel."[1]

By Charles Beresford Fox, B.A., Stud. Inst. C.E.

Before entering upon a description of the constructive details of this, the longest railway tunnel in the world, it may be well to give a general idea of the undertaking. Many schemes for the connection of Italy and Switzerland by a railway near the Simplon Road Pass have been devised, including one involving no great length of underground work, the line mounting by steep gradients and sharp curves. The present scheme, put forward in 1881 by the Jura-Simplon Railway Company, consists broadly of piercing the Alps between Brieg, the present railway terminus in the Rhone Valley, and Iselle, in the gorge of the Diveria, on the Italian side, from which village the railway will descend to the existing southern terminus at Domo d'Ossola, a distance of about 11 miles.

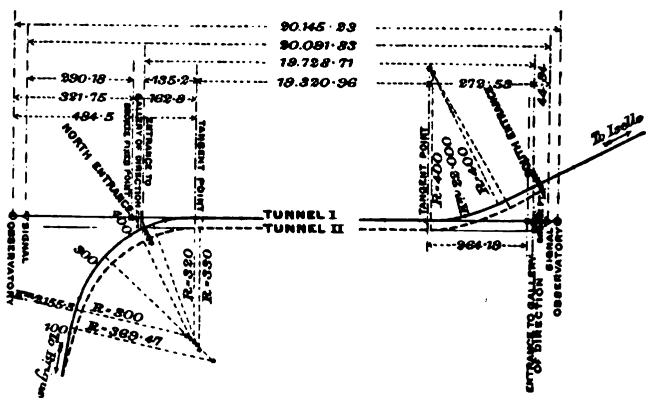
In conjunction with this scheme a second tunnel is proposed, to pierce the Bernese Alps under the Lötschen Pass from Mittholz to a point near Turtman in the Rhone Valley, and thus, instead of the long detour by Lausanne and the Lake of Geneva, there will be an almost direct line from Berne to Milan *viâ* Thun, Brieg, and Domo d'Ossola.

Starting from Brieg, the new line, running gently up the valley for 1¼ mile, will, on account of the proximity of the Rhone, which has already been slightly diverted, enter the tunnels on a curve to the right, of 1,050 feet radius, *Fig. 1.* At a distance of 153 yards from the entrance, the straight portion of the tunnels commences, and extends for 12 miles. The line then curves to the left with a radius of 1,311 feet before emerging on the left bank of the Diveria. Commencing at the northern entrance, a gradient of 1 in 500 (the minimum for efficient drainage) rises for a length of 5½ miles to a level length of 550 yards in the centre, and then a gradient of 1 in 143 descends to the Italian side.

[1] This Paper was read and discussed at a Students' Meeting on the 26th January, 1900.

On the way to Domo d'Ossola one helical tunnel will be necessary, as has been carried out on the St. Gothard. There will be eventually two parallel tunnels, having their centres 56 feet apart, each carrying one line of way, but at the present time only one heading, that known as No. 1, is being excavated to full size, No. 2 being

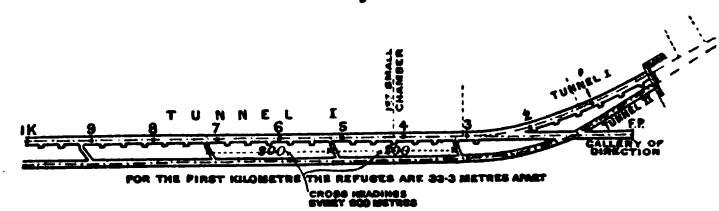
Fig. 1.



PLAN OF TUNNELS.

left, masonry lined where necessary, for future developments. By means of cross headings every 220 yards the problems of transport and ventilation are greatly facilitated, as will be seen later. As both entrances are on curves, a small "gallery of direction" is necessary, to allow corrections of alignment to be made direct from the two observatories on the axis of the tunnel, *Fig. 2*.

Fig. 2.



PLAN SHOWING "GALLERY OF DIRECTION" AND CROSS-HEADINGS.

The outside installations are as nearly in duplicate as circumstances will allow, and consist of the necessary offices, workshops, engine-sheds, power-houses, smithies, and the numerous buildings entailed by an important engineering scheme. Great care is taken that the miners and men working in the tunnel shall not suffer

from the sudden change from the warm headings to the cold Alpine air outside, and for this purpose a large building is in course of erection, where they will be able to take off their damp working clothes, have a hot and cold douche, put on a warm dry suit, and obtain refreshments at a moderate cost before returning to their homes. Instead of each man having a locker in which to stow his clothes, a perfect forest of cords hang down from the wooden ceiling, 25 feet above floor-level, each cord passing over its own pulleys and down the wall to a numbered belaying pin. Each cord supports three hooks and a soap-dish, which, when loaded with their owner's property, are hauled up to the ceiling out of the way. There are 2,000 of these cords, spaced 1 foot 6 inches apart, one to each man. The engineers and foremen are more privileged, being provided with dressing-rooms and baths, partitioned off from the two main halls. An extensive clothes-washing and drying plant has been laid down, and also a large restaurant and canteen. At Iselle, a magazine holding 2,200 lbs. of dynamite is surrounded and divided into two separate parts by earth-banks, 16 feet high. The two wooden houses, in which the explosive is stored, are warmed by hot-water pipes to a temperature between 61° F. and 77° F. and are watched by a military patrol, but at Brieg a dynamite manufactory, started by an enterprising company at the time of the commencement of the works, supplies this commodity at frequent intervals, thereby avoiding the necessity of storing in such large quantities. This dynamite factory has been largely increased, and supplies dynamite to nearly all the mining and tunnelling enterprises in Switzerland.

Geological Conditions.—Before the Simplon Tunnel was authorized, expert evidence was taken as to the feasibility of the project. The forecasts of the three engineers chosen, in reference to the rock to be encountered and its probable temperature, have, as far as the galleries have gone (an aggregate distance of nearly 2½ miles), generally been found correct. At the north end, a dark argillaceous schist veined with quartz was met with, and from time to time beds of gypsum and dolomite have been traversed, the dip of the strata being on the whole favourable to progress, though timbering is resorted to at dangerous places. Water was plentiful at the commencement; in fact, one inrush has not been stopped, and is still flowing down the heading. The total quantity of water flowing from the tunnel mouth is 16 gallons per second, of which 2 gallons per second are accounted for by the drilling machines. At Iselle, however, a very hard antigorio gneiss obtains, and is likely to

extend for 4 miles. Very dry and very compact, it requires no timbering, and presents no great difficulty to the powerful Brandt rock-drills, which work under a head of 3,280 feet of water.

The temperature of the rock depends not only on the depth from the surface, but largely upon the general form of that surface combined with the conductivity of the rock. Taking these points into consideration with the experience gained from the construction of the St. Gothard Tunnel, 95° F. was estimated as the probable maximum temperature, owing to the height of Monte Leone (11,660 feet), which lies almost directly over the tunnel axis.

Survey.—After having determined upon the general position of the tunnels, taking into consideration the necessary gradients, the temperature of the rock, and a large bed of troublesome gypsum on the north side, two fixed points on the proposed centre line were taken, one at each entrance of tunnel No. 1, and the bearings of these two points, with reference to a triangulation survey made in 1876, were calculated sufficiently accurately to determine, for the time being, the direction of the tunnel. In 1898, a new triangulation survey was made, taking in eleven summits, Monte Leone holding the central position. This survey was tied into that of the Wasenhorn and Faulhorn, made by the Swiss Government, and the accuracy was such that the probable error in the meeting of the two headings is only 6 centimetres, or 2½ inches.

On the top of each summit is placed a signal, consisting of a small pillar of masonry founded on rock and capped with a sharp-pointed cone of zinc, 1 foot 6 inches high. An observatory was built at each end of the tunnel in such a position that three of the summits could be seen, a condition very difficult to fulfil on the south side owing to the depth of the gorge, the mountains on either side being over 7,000 feet high. Having taken the angles to and from each visible signal, and therefrom having calculated the direction of the tunnel, it was necessary to fix, with extreme accuracy, sighting points on the axis of the tunnel, in order to avoid sighting on to the surrounding peaks for each subsequent correction of the alignment of the galleries. To do this, a theodolite 24 inches long and 2⅜ inches in diameter, with a magnifying power of forty times, was set up in the observatory, and about 100 readings were taken of the angles between the surrounding signals and the required sighting points. In this manner the error likely to occur was diminished to less than 1 second. Thus at the north end two points were found about 550 yards before

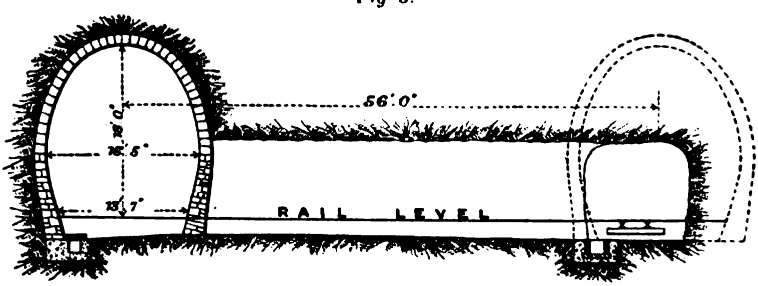
and behind the observatory, while on the south side, owing to the narrowness of the gorge, the points could only be placed at 82 yards and 126 yards in front. One of these sighting points consists of a fine scratch ruled on a piece of glass fixed in an iron frame, behind which is placed an acetylene lamp—corrections of alignment are always done by night—the whole being rigidly fixed into a niche cut in the rock and protected from climatic and other disturbing agencies by an iron plate.

Method of Checking Alignment.—The direction of heading No. 1 is checked by experts from the Government Survey Department at Lausanne about three times a year, and for this purpose a transit instrument is set up in the observatory. To avoid loss of time—£200 premium or fine being fixed for every day before or after the contract date of completion—a number of three-legged iron tables are placed at intervals of 1 mile or 2 miles along the axis of tunnel No. 1, and upon each of these is placed a horizontal plane, movable by means of an adjusting screw, in a direction at right angles to the axis, along a graduated scale. On this plane are small sockets, into which the legs of an acetylene lamp and screen, or of the transit instrument, can be quickly and accurately placed. The screen has a vertical slit, 3 inches in height and variable between $\frac{13}{16}$ inch and $\frac{3}{16}$ inch in breadth, according to the state of the atmosphere, and at a distance shows a fine thread of light. The instrument, having first been sighted on to the illuminated scratch of the sighting point, is directed up the tunnel, where a thread of light is shown from the first table. With the aid of a telephone this light is adjusted so that its image is exactly coincident with the cross hairs, and the reading on the graduated scale is noted. This is done four or five times, the average of these readings being taken as correct, and the plane is clamped to that average. The instrument is then taken to the first table and is placed quickly and accurately over the point just found (by means of the sockets), and the lamp is carried to the observatory. After first sighting back, a second point is given on the second table, and so on. These points are marked either temporarily in the roof of the heading by a short piece of cord hanging down, or permanently by a brass point held by a small steel cylinder, 8 inches long and 3 inches in diameter, embedded in concrete in the rock floor, and protected by a circular casting, also sunk in cement concrete, holding an iron cover resembling that of a small manhole. From time to time the alignment is checked from these points by the engineers, and after each blast the general direction is given by the hand from the temporary points. To check the results of the

triangulation survey, astronomical observations have been taken simultaneously at each end. With regard to the levels, those given on the excellent Government surveys have been taken as correct, but they have also been checked over the pass.

Details of Tunnels.—In cross section, tunnel No. 1 is 13 feet 7 inches wide at formation level, increasing to 16 feet 5 inches, with a total height of 18 feet above rail-level and a cross-sectional area of about 250 square feet. This large section will allow of small repairs being executed in the roof without interruption of the traffic, and will also allow of strengthening the walls by additional masonry on the inside. The thickness of the lining, never wholly absent, and the material of which it is composed, depend upon the pressure to be resisted, and only in the worst case is inverting resorted to. The side drain, to which the rock floor is made to slope, will be composed of half pipes of 7 to 1 cement concrete. The roof is constructed of radial stones.

Fig 3.



Scale, 1 inch = 20 fe t.

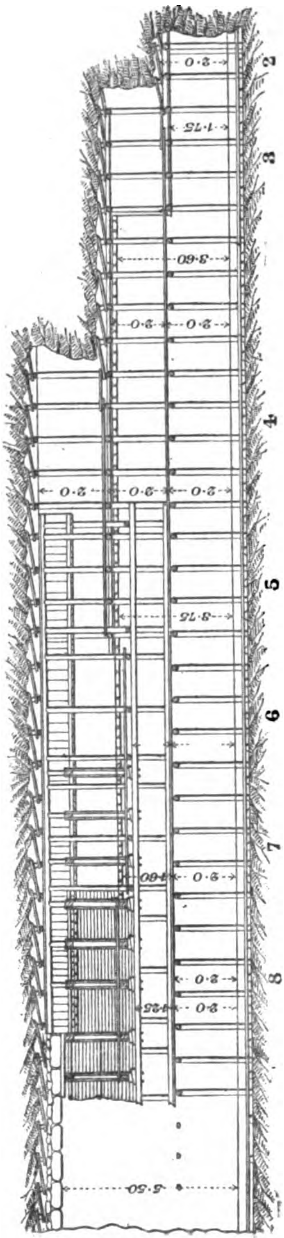
SECTION ALONG A CROSS-HEADING.

Tunnel No. 2, being left as a heading, is driven on that side nearest to No. 1, to minimize the length of the cross headings, and measures 10 feet 2 inches wide by 6 feet 7 inches high, *Fig. 3*. Masonry is used only where necessary, and in that case is so built as to form part of the lining of the tunnel when eventually completed. Concrete is put in to form a foundation for the side wall, and a water channel. The cross headings, connecting the two parallel headings, occur every 220 yards, and are placed at an angle of 56° to the axis of the tunnel, to avoid sharp curves in the contractors' railway lines. They will eventually be used as much as possible for refuges, chambers for storing the tools and equipment of the platelayers, and signal-cabins. The refuges, 6 feet 7 inches wide by 6 feet 7 inches high and 3 feet 3 inches deep, occur every 110 yards, every tenth being enlarged to 9 feet

10 inches wide by 9 feet 10 inches deep and 10 feet 2 inches high, still larger chambers being constructed at greater intervals.

Method of Excavation.—The work at each end of the tunnel is carried on quite independently, consequently, though similar in principle, the methods vary in detail, apart from the fact that different geological strata require different treatment. Broadly speaking, the two parallel headings, each 59 square feet in section, are first driven by means of drilling machines and the use of dynamite, this work being carried on day and night, 7 days in the week; No. 1 heading is then enlarged to full size by hand-drilling and dynamite. On the Italian side, where the rock is hard and compact, break-ups are made at intervals of 50 yards, and a top gallery is driven in both directions, but, for ventilation reasons, is never allowed to get more than 4 yards ahead of the break-up, which is gradually lengthened and widened to the required section. No timbering is required, except to facilitate the excavation and the construction of the side walls. Steel centres are employed for the arch; they entail fewer supports, give more room, and are capable of being used over again more frequently, without damage. They consist of two I beams bent to a template and riveted together at

Fig. 4.

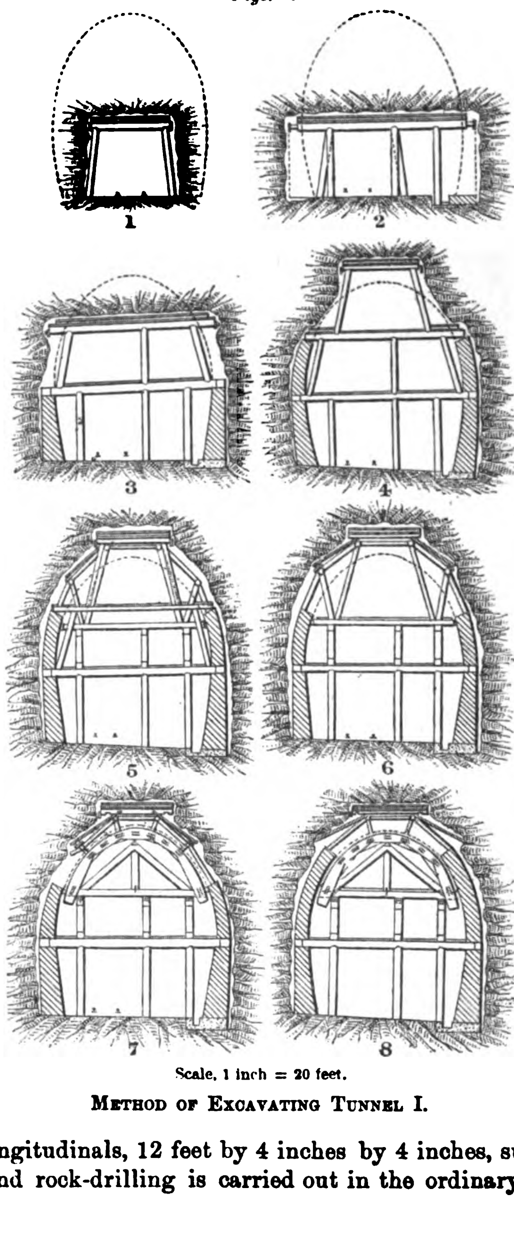


Scale, 1 inch = 20 feet.

LONGITUDINAL SECTION OF TUNNEL: SHOWING TIMBERING.

the crown, resting at either side on scaffolding at intervals of

Figs. 5.



Scale, 1 inch = 20 feet.

METHOD OF EXCAVATING TUNNEL I.

6 feet; longitudinals, 12 feet by 4 inches by 4 inches, support the roof. Hand rock-drilling is carried out in the ordinary way, one

man holding the tool and a second striking; measurements of excavation are taken every 2 or 3 yards, a plumb-line is suspended from the centre of the roof, and at every half metre (20 inches) of height horizontal measurements are taken to each side.

At the Brieg end a softer rock is encountered, necessitating at times heavy timbering in the heading, and especially in the final excavation to full size, *Figs. 4* and *5*. The bottom heading, 6 feet 6 inches high, is driven in the centre, and the heading is then widened to the full extent and timbered; the concrete forming the water channel and the foundation for one side wall is put in; the side walls are built to a height of 6 feet 6 inches, and the tunnel is fully excavated to a further height of 6 feet 6 inches from the first staging. The side walls are then continued up for the second 6 feet 6 inches, and from the second floor a third height of 6 feet 6 inches is excavated and timbered. Finally the crown is cleared out, heavy wooden centres are put in, the arch is turned and all timbers are withdrawn except the top poling boards, supporting the loose rock.

The masonry for the side walls is obtained either from the tunnel itself or from a neighbouring quarry, and varies in character according to the pressure, but the face of the arch is always of cut or artificial stones, the latter being of 7 to 1 cement concrete. Where the alignment heading, or the "gallery of direction," joins the curving portion of tunnel No. 1, the section is very much greater, and necessitates special timbering.

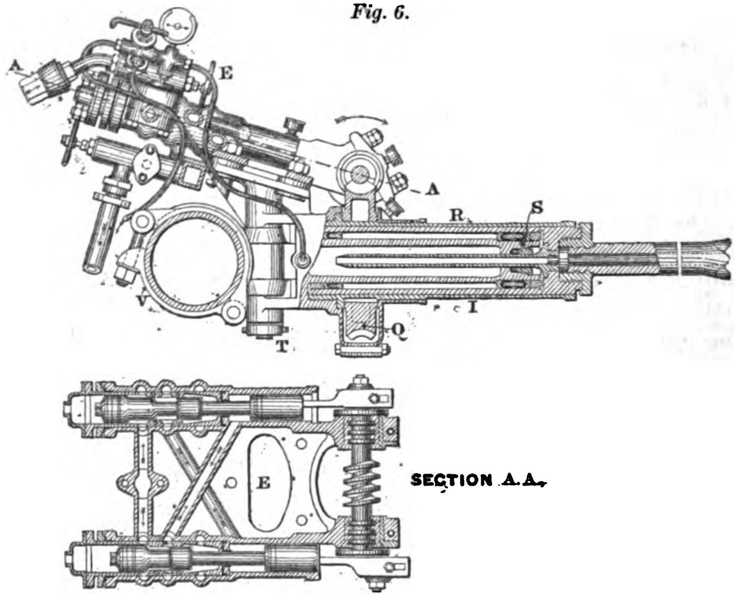
Transport—Italian Side.—A small line of railway, 2 feet 7½ inches gauge, with 40-lb. rails, enters all three portals, but since the construction of a wooden bridge over the Diveria, the route through the "gallery of direction," across heading No 2, to tunnel No. 1, is used exclusively; this railway leads to the face in both headings, and, where convenient, from one heading to the other by the cross galleries. Different types of wagons are in use, but in general they are four-wheeled, non-tipping box wagons, supplied with brakes and holding 2 cubic yards of debris. A special type of locomotive is used, designed to pass round curves of 50 feet radius, and supplied with a specially large boiler to avoid firing in the tunnel. (Dimensions of the locomotive are given in the Paper.)

Method of Working.—The drilling machines employed are of the Brandt type, *Fig. 6*, and are mounted in the following manner. A small four-wheeled carriage supports at its centre a beam, the shorter arm of which carries the boring mechanism and the longer a counterpoise; near its centre is the distributor. In the short arm is a clamp holding the rack-bar or butting column, which

is a wrought-iron cylinder with a plunger constituting a ram, and is jammed by hydraulic pressure between the walls of the heading, thus forming a rigid support for the boring machine, and an efficient abutment against the reaction of the drill. This rack-bar can be rotated on its clamp in a plane parallel to the axis of the beam. Three or four separate boring-machines can be mounted on the rack-bar, and can be adjusted in any reasonable position.

The boring machine performs the double function of continually pressing the drill into the rock by means of a hollow ram (I) and of imparting to the drill and ram a uniform rotary motion. This

Fig. 6.



Scale, $\frac{3}{4}$ inch = 1 foot.

"BRANDT" HYDRAULIC ROCK-DRILL.

rotary motion is given by a twin cylinder single-acting hydraulic motor (E), the two pistons, of $2\frac{3}{8}$ inches stroke, acting reciprocally as valves. The cranks are fixed at an angle of 90° to each other on the shaft, which carries a worm, gearing with a wormwheel (Q) mounted upon the shell (R) of the hollow ram (I), and this shell in turn engages the ram by a long feather, leaving it free to slide axially to or from the face of the rock. The average speed of the motor is 150 revolutions to 200 revolutions per minute, the maximum speed being 300 revolutions per minute. The loss of power between the worm and wormwheel is only 15 per cent. at

the most; the worm being of hardened steel and the wheel of gun-metal, the two surfaces in contact acquire a high degree of polish, resulting in little wearing or heating. Taking into consideration all other sources of loss, 70 per cent. of the total power is utilised. The pressure on the drill is exerted by a cylinder and hollow ram (I), which revolves about the differential piston (S), which is fixed to the envelope holding the shell (R). This envelope is rigidly connected to the bed-plate of the motor, and, by means of the vertical hinge and pin (T), is held by the clamp (V) embracing the rack-bar. When water is admitted to the space in front of the differential piston the ram carrying the drilling-tool is thrust forward, and when admitted to the annular space behind the piston, the ram recedes, withdrawing the tool from the blast-hole. The drill proper is a hollow tube of tough steel $2\frac{3}{4}$ inches in external diameter, armed with three or four sharp and hardened teeth, and makes 5 revolutions to 10 revolutions per minute, according to the nature of the rock. When the ram has reached the end of its stroke of 2 feet $2\frac{1}{2}$ inches, the tool is quickly withdrawn from the hole and unscrewed from the ram; an extension rod is then screwed into the tool and into the ram, and the boring is continued, additional lengths being added as the tool grinds forward; each change of tool or rod takes about 15 seconds to 25 seconds to perform. The extension rods are forged steel tubes, fitted with four-threaded screws, and having the same external diameter as the drill. They are made in standard lengths of 2 feet 8 inches, 1 foot 10 inches, and $11\frac{3}{4}$ inches. The total weight of the drilling-machine is 264 lbs., and that of the rack-bar when full of water is 308 lbs. The exhaust-water from the two motor cylinders escapes through a tube in the centre of the ram and along the bore of the extension-rods and drill, thereby scouring away the debris and keeping the drill cool; any superfluous water finds an exit through a hose below the motors and thence away down the heading. The distributor, already mentioned, supplies each boring-machine and the rack-bar with hydraulic pressure from the mains, with which connection is effected by means of flexible or articulated pipe connections, allowing freedom in all directions. The area of the piston for advancing the tool is $15\frac{1}{2}$ square inches, which under a pressure of 1,470 lbs. per square inch gives a pressure of over 10 tons on the tool, while for withdrawing the tool $2\frac{1}{2}$ tons is available. In the rock found at Iselle, namely, antigorio gneiss, a hole $2\frac{3}{4}$ inches in diameter and 3 feet 3 inches in length is drilled, normally, in 12 minutes to 25 minutes; a daily rate of advance of 18 feet to 19 feet 6 inches is made in a heading

having a minimum cross-section of 59 square feet; the time taken to drill ten to twelve holes, 4 feet 7 inches deep, is 2½ hours.

When the debris resulting from one operation has been sufficiently cleared away, a steel flooring, which is provided near the face to enable shovelling to be more easily done and to give an even floor for the wheels of the drilling carriage, is laid bare at the head of the line of rails, and the drilling machines are brought up on their carriage by eight or ten men. When advanced sufficiently close to the face, the rack bar is slewed round across the gallery and is wedged up against the rock sides; connection is made between the distributor and the hydraulic main, by means of the flexible pipe, and pressure is supplied by a small copper tube to the rack-bar ram, thereby rigidly holding the machine. Next, connections are made between the three drilling machines and the distributor, and in 20 minutes from the time the machine was brought up all three drills are hard at work, water pouring from the holes.

The noise of the motors and grinding tools is sufficient to drown all but shouts, and where the extension rods do not fit tightly, small jets of water play in all directions, necessitating the wearing of tarpaulins by the men directing the tools. Lighting is done wholly by small oil-lamps, provided with a hook to facilitate fixing in any crack in the rock; electricity will probably be used to light that portion of the tunnel which is completed.

Two men are allotted to each drill, one to drive the motor, the other to direct and replenish the tool, one foreman and two men in reserve completing the gang. A small hammer is freely used to loosen the screw joints of the extension rods and drill. A hole is usually commenced by a two-edged flat-pointed tool, until a sufficient depth is reached to prevent the circular tool from wandering over the face of the rock, but in many instances the hole is commenced with a circular tool. The exhaust water during this period flows away by the hose underneath the motor. In the antigorio gneiss, ten to twelve holes are drilled for each attack, three or four in the centre to a depth of 3 feet 3 inches, the remainder, disposed round the outside of the face, having a depth of 4 feet 7 inches. The average time taken to complete the holes is 1¾ hour to 2½ hours. Instead of pulverising the rock, as do the diamond drills, it is found that the rock is crushed, and that headway is gained somewhat in the manner of a circular saw through wood. The core of rock inside the tool breaks up into small pieces, and can be taken out if necessary when the drill requires lengthening.

The lowest holes, inclined downwards, are full of water; consequently two detonators and two fuses are inserted, but apart from this, water has little effect on the charge. The fuses of the central holes are brought together and cut off shorter than those of the outer holes, in order that they may explode first, to increase the effect of the outer charges. All portable objects such as drills, pipe connections, tools, etc., have meanwhile been carried back; the steel flooring is covered over with a layer of debris to prevent injury from falling rock, and to the end of the hydraulic main is screwed a brass plug pierced by five holes, and immediately the explosions occur a valve is opened in the tunnel and five jets of water play upon the rock, laying the dust and clearing the air. The necessity for this was shown on one occasion when this nozzle was broken by the explosion and the water had to be turned off immediately to avoid useless waste; on reaching the face, the atmosphere was found to be so highly charged with dust and smoke that it was impossible to distinguish the stones at the feet, although a lamp had been placed on the ground, and despite the fact that the air tube was in full blast, the men experienced great difficulty in breathing. A truck is now brought up, and four men clear a passage in front, through the heap of debris, two with picks and two with shovels, while on either side and behind are as many men as space will permit. The stone is thrown either to the sides of the heading or into the wagon, shovelling being greatly aided by the steel flooring, which, before the explosion, had been laid over the rails for nearly 10 yards down the tunnel to receive the falling rock. These steel plates are taken up when cleared, and the wagon is pushed forward until the drilling machine can be brought up again, leaving the remaining debris at the sides to be handled at leisure during the next attack. The roof and side walls are of course carefully examined with the pick, to discover and detach any loose or hanging rock. The times taken for each portion of the attack in this particular antigorio gneiss are as follows:—Bringing up and adjustment of drills, 20 minutes; drilling, between 1¾ hour and 2½ hours; charging and firing, 15 minutes; clearing away debris, 2 hours; or for one whole attack, between 4½ hours and 5½ hours, resulting in an advance of 3 feet 9 inches, or a daily advance of nearly 18 feet.

From this it appears that the time spent in clearing away the debris equals that taken up in drilling, and it is in this clearing that a saving of time is likely to be effected rather than in the process of drilling. Many schemes have been tried, such as a mechanical plough for making a passage; at Brieg, "marinage,"

or clearing by means of powerful high pressure water-jets, directed down the tunnel was tried, but the idea is not yet sufficiently developed.

Another series of experiments have been tried at Brieg with regard to the utilization of liquid air as an explosive agent instead of dynamite, and for this purpose a plant has been laid down, consisting of one ammonia-compressor, two air-compressors, and two refrigerators, furnishing 1·10 gallon of liquid air per hour at an expenditure of 17 HP. The system used is that of Professor Linde, who himself directs the experiments. The great difficulty experienced is that of shortening the interval of time that must elapse between the manufacture of the cartridge and its explosion. The liquid oxygen, with which the cartridge, containing kieselguhr (silicious earth) and paraffin, is saturated, evaporates very readily, losing power every moment; hence the effect of each cartridge cannot be guaranteed, and though it is an exceedingly powerful explosive when used immediately after manufacture, no practical result has yet been obtained.

Power Station.—Water is abundant at either end, and therefore hydraulic power is the motive force employed. On the Italian side, a dam 5 feet high has been thrown across the Diveria at a point near the Swiss frontier, about 3 miles above the site of the installations. A portion of the water thus held back enters, through regulating doors and gratings, a masonry channel leading to two parallel settling tanks, each 111 feet by 16 feet, whence, after dropping all its sand and solid matter, the now pure water passes into the water-house, and, after flowing over a dam, through a grating, and past the admission doors, enters a metallic conduit of 3-foot pipes. Each of the settling tanks and the approach canal are provided with doors at the lower end leading direct to the river, through which all the sand and solid matter deposited can be scoured naturally by allowing the river-water to rush freely through. For this purpose the floor of the basins is on an average gradient of 1 in 30. For a similar reason the river-bed just outside the entrance to the approach canal is lined with wooden planks, from which the stones collecting behind the dam can be scoured by allowing an iron flap, hinged at the bottom, to change its position from the vertical to the horizontal in a gap left purposely in the dam, so causing a rushing torrent to sweep it clean.

The chief levels are :—

Level of water at dam	794·00	metres above sea-level.
„ „ in water-house . .	793·70	„ „ „ „
„ „ at turbines . . .	618·50	„ „ „ „

giving a total fall of 175·20 metres or 570 feet, and a pressure of 17·52 atmospheres.

The quantity of water capable of being taken from the Diveria in winter, when the rivers which are dependent upon the mountain snows for their supply are at their lowest, is calculated to be 352 gallons per second. Thus, taking the fall to be diminished by friction, etc., to 440 feet, and the useful effect at 70 per cent., there is obtained 2,000 HP. on the turbine shaft.

The metallic conduit varies in material according to the pressure; thus cast-iron pipes 3 feet in diameter and $\frac{13}{16}$ inch thick are used up to a pressure of 2 atmospheres, from which point they are of wrought iron. The cast-iron portion has of late caused a good deal of trouble, owing to settlement of the piers causing occasional bursts, consequently a masonry pier has been placed under each joint of this portion. The following Table gives the thicknesses and diameters, varying with the pressure:—

Water Pressure.	Thickness.		Diameter.		Weight per Yard.
Head in Feet.	Milli-metres.	Inch.	Feet.	Inches.	Lbs.
246	6	$\frac{1}{4}$	3	0	326
311	7	..	3	0	383
360	8	..	3	0	431
393	9	..	3	0	483
426	10	..	3	0	556
476	12	..	3	0	651
590	16	$\frac{5}{8}$	3	$3\frac{1}{8}$	977

This pipe is supported every 30 feet on small masonry piers, on the top of which is placed a block of wood hollowed out to receive the pipe, thus allowing any movement due to the contraction and expansion of the conduit. However, to prevent this movement becoming excessive, the pipe is passed at intervals of 300 yards to 500 yards through a cubical block of masonry of 13 feet side, strengthened by longitudinal tie-bars. Five bands of angle-bar riveted round the pipe, with their flanges embedded in the masonry, constitute a rigid fixed point. Straw mats are thrown over the pipe where it is exposed to the sun. The temperature of the conduit is not, however, found to vary greatly, since the pipe is kept full of water. To supply the rock-drills with water at a maximum pressure of 100 atmospheres, or 1,470 lbs. per square inch, a plant of four pairs of high-pressure pumps has been laid down, and a still larger addition is in course of erection. At present, two Pelton turbines of 250 HP. each, running at 170 revolutions per

minute, drive the pumps, by means of toothed gearing, at 63 revolutions per minute. These pumps are of very simple but strong construction, single suction and double delivery, entailing one suction- and one delivery-valve, both heavy and both of small lift. The larger portion of the plunger has exactly double the cross-sectional area of the smaller portion, so that in the forward stroke half of the water taken in at the last admission is pumped into the high-pressure mains, and at the same time a fresh supply of water is sucked in. During the backward stroke half of this new supply is pumped into the mains, and the remainder enters the second chamber, to be pumped during the next forward stroke. Thus the work done in the two strokes is practically the same. The pumps are in pairs, and are set at an angle of 90°, to ensure uniform pressure and uniform delivery in the mains. Their size varies, but at Iselle there are three pairs, with a stroke of 2 feet 2½ inches, and plungers of 2$\frac{11}{16}$ inches and 1⅞ inch (approximately) in diameter, supplying 1·32 gallon per second.

To avoid injury to the valves, the water to be pumped is taken from a stream up the mountain side, and is passed through filter screens. The high-pressure water, after passing an accumulator, enters the tunnel in solid drawn wrought-iron tubes, 3⅛ inches in internal diameter, $\frac{3}{16}$ inch thick, and in lengths of 26 feet. The diameter of these mains varies with their length, so as to avoid loss of pressure. With the 1,250 yards of tunnel now driven 10 atmospheres are lost.

At Brieg the installations are, as far as possible, identical. The Rhone water, however, before reaching the water-house is carried from the filter basins, a distance of 2 miles, in an armoured canal built upon the Hennebique system, the walls and supporting beams, of cement concrete, being strengthened by internal tie-bars of steel. The concrete struts, resembling baulks of timber at a distance, are occasionally 35 feet high and 1 foot 7½ inches square. The metallic conduit is 5 feet in diameter, with a minimum flow of 176 cubic feet per second and a total fall of 185 feet. In case water-power should be unavailable, three semi-portable steam-engines, two of 80 HP. and one of 60 HP., are always kept in readiness at each end of the tunnel, and are geared by belts to the turbine shaft.

Ventilation.—In tunnelling, one of the most important problems to be solved is that of ventilation, and it is for this reason that the Simplon Tunnel consists of two parallel headings with cross cuts at intervals of 220 yards. At Brieg, a shaft 164 feet deep was sunk through the overlying rock until the "gallery of direction" was

encountered. Up this chimney the foul air is drawn by wood fires, the fresh air—a volume of 19 million cubic feet per day, or 13,200 cubic feet per minute—entering by heading No. 2, penetrating up to the last cross gallery, and returning by tunnel No. 1. The entrances of No. 1 and the "gallery of direction," besides those of all the intermediate cross galleries, are closed by doors. By this arrangement, however, fresh air does not reach the working faces, therefore a pipe, 8 inches in diameter, is led from the fresh air in No. 2 to within 15 yards of the face of each heading, and up this pipe a draught of air is induced by means of a jet of water, the volume to each face being 800 cubic feet per minute. One single jet of water from the high-pressure mains, with a diameter of $\frac{1}{16}$ inch, is capable of supplying over 1,000 cubic feet of air per minute at the end of 160 yards of pipe, and during the attack the men at the drills are in a constant breeze with the thermometer standing at 70° F. At Iselle, air is blown into the entrance of heading No. 2 at the rate of 14,100 cubic feet per minute by two fans driven from the turbine shaft. This air travels from the fans along a pipe, 18 inches in diameter, till a point 15 yards up the tunnel is reached, where beyond a door the pipe narrows to form a nozzle 10 inches in diameter. This door is kept open to allow the outside air to be induced up the tunnel, as the headings are at present only 2,500 yards long, giving a resistance of not quite sufficient power to cause the air to return. The fresh air then travels up No. 2, crossing over the top of the "gallery of direction," from which it is shut off by doors, to the last cross gallery, returning by No. 1, and finally leaving either by the "gallery of direction" or by No. 1, *Fig. 2.* A system of cooling the air and driving it on by means of a large number of water-jets will be installed in No. 2 where that heading crosses over the "gallery of direction," but at present there is no need for it.

The average temperature at the face is 73° F. during the drilling operation, 76° F. after firing the charges, and a maximum of 80° F., lately attaining to 86° F. on the south side, with 80° F. and 85° F. before and after firing. The temperature of the rock is taken at every 110 yards in holes 5 feet deep, and shows a gradual increase according to the depth of overlying rock, to the conductivity of the rock, and to the form of the mountain surface. The maximum hitherto reached on the north side is 68° F., while on the south side, although a smaller distance has been traversed, it attains to 79° F., due to the more rapid increase in depth. Moreover, the temperature of the rock is observed at the permanent stations, 550 yards from the entrances, in its relation to that of the tunnel

and outside air, and though on the north side that of the rock varies almost as quickly as that of the tunnel air, on the south it is influenced very much less.

A few statistics may be of interest with regard to the progress of the last 3 months (taken from the trimestrial report of January, 1900). At Brieg, where there are three drilling machines in No. 1 and two in the parallel heading, the total length excavated was 995 yards or 6,409 cubic yards in 89 working days, the average cross-sectional area being 57 square feet. This required 507 attacks and 3,066 holes, which had a total depth of 26,600 feet, and 14,700 re-sharpenings of the drilling tool, with 44,000 lbs. of dynamite.

The average time occupied in drilling was 2 hours 45 minutes, while charging, firing, and clearing away the debris took 6 hours 35 minutes. At Brieg 648 men and 29 horses were employed at one time in the tunnel. At Iselle the numbers were 496 men and 16 horses, working in shifts of 8 hours. Outside the tunnel, in the shops, forges, etc., the men work 8 hours to 11 hours per day, the total being 541 men at Brieg and 346 men at Iselle. On the Italian side, where the rock is very much harder, there were three drilling machines in each heading; the total length excavated, with a cross-sectional area of 62 square feet, was 960 yards or 6,700 cubic yards in 91 working days. This required 61,293 re-sharpened tools, 758 attacks, 7,940 holes with a total depth of 33,000 feet, and 56,000 lbs. of dynamite. The average time spent in drilling was 2 hours 55 minutes, and in charging and clearing 2 hours 36 minutes. Thus, in the hard gneiss, to excavate 1 cubic yard of rock required 8½ lbs. of dynamite, and each tool pierced 6½ inches of rock before it required re-sharpening.

Up to January 1, 1900, the total length of heading on the north side was 2,515 yards, and on the south side 1,720 yards, or a total of 4,235 yards out of 21,575 yards, the full length of the tunnel. Allowing for unavoidable and unforeseen occurrences, such as strikes, war, etc., the contractors expect to complete tunnel No. 1 and the parallel heading by May, 1904.

The Paper is accompanied by drawings, from which the Figures in the text have been prepared.

OBITUARY.

WILLIAM BUTTERTON, born on the 25th April, 1854, began his engineering career as a pupil in the office of Messrs. Butterton and Light, Civil Engineers, of Westminster. He was subsequently employed from 1875 to 1882 in assisting Messrs. Nimmo and McNay and Mr. G. W. Willcocks and others, in railway and tramway works; and during a portion of that period he had charge of the construction, at Haggerston, of a large gas-holder tank, erected for the Imperial Gaslight Company. From 1879 to 1882 he was engaged in preparing for Mr. John Russell the Parliamentary plans and sections for several railways in England and Ireland, in setting out for contract and preparing drawings and estimates for the Belfast and High Hollywood Railway, and in setting out and locating the line between Portrush and the Giant's Causeway. He was likewise employed at various times on contract-surveys and estimates for the late Mr. G. P. Bidder, Past-President, and on general office work, levels, tidal observations, and inspection of materials for Mr. W. J. Kingsbury.

Early in 1882 Mr. Butterton was placed in charge of a survey of 105 miles for the extension of the Natal Government Railways between Ladysmith and the Transvaal Frontier, across the chief ranges of mountains, for which work the late Sir (then Mr.) George Berkley, Past-President, was the Consulting Engineer. On the completion of that survey in the spring of 1884, Mr. Butterton was appointed District Maintenance Engineer, in responsible charge of from 100 miles to 150 miles of the railways open for traffic, including also reconstruction works. He acted subsequently as District Engineer for the Charlestown-Johannesburg extension. In 1897 Mr. Butterton resigned the Government service and started private practice in Durban as an engineer and contractor, and in July, 1899, he returned to England in failing health. Unfortunately the change did not have the desired effect, and he died in London on the 18th November, 1899. Mr. Butterton was an able engineer, conscientiously devoted to his work. Courteous in manner and ever ready to assist his younger brethren, he was much esteemed by all associated with him.

He was elected an Associate Member of the Institution on the 14th April, 1885, and was transferred to the class of Members on the 11th December, 1888.

EDWARD COUSINS died at his residence, Cadoxton, St. Albans, on the 30th December, 1899, after a long period of ill health. Born at Alnwick, Northumberland, in 1820, he served articles to Mr. John Dobson, of Newcastle-on-Tyne, with whom he remained subsequently as an Assistant. About the year 1853 Mr. Cousins was appointed Borough Engineer to the Corporation of Swansea, which post he held for twenty-nine years. During that period he designed and carried out an extension of the waterworks for the supply of the Borough, including a reservoir with an embankment 80 feet in height; the completion of the Cwm Donkin Reservoir; the construction of a subway under the River Tawe; the laying of about 150 miles of water-mains; and a system of drainage for Swansea, Pentre, Landore, Morriston, the hamlet of St. Thomas Foxhole and Gwendy.

Towards the end of 1882 Mr. Cousins resigned the post of Borough Engineer of Swansea and began to practise on his own account in Westminster. He soon acquired considerable reputation as an authority on sanitary matters, and his evidence was frequently sought in Parliamentary inquiries. During the greater part of 1891 he was engaged on the important work of reporting for the Indian Government on the best means of procuring effective drainage and water-supply for the town of Madras. He was then over seventy years of age, and unfortunately his health suffered from the effects of the Indian climate. Shortly before his death he was occupied, in conjunction with his son, as engineer for the construction of drainage works for Bridgend, South Wales.

Mr. Cousins was elected a Member of the Institution on the 4th February, 1879.

FREDERICK BERNARD DOERING was born on the 8th July, 1838. At the age of fifteen, he was sent to Dortmund, in Germany, to school, where he remained two years, and was then apprenticed to underground work at the Nachtigall Mine, in Westphalia. In 1856 he was engaged on a difficult sinking of a round shaft, through 400 feet of marl, interspersed with layers of quicksand, at the Java Mine. In the following year he entered, as an apprentice, the engine works of Messrs. Fawcett, Preston and Co., Liverpool, and in June, 1861, he passed the competitive examination for admission to the Public Works

Department of the Government of India, and was appointed an Assistant Engineer on the Bari Doâb Canal Works in the Punjâb. Owing to bad health, he was obliged to resign the service in 1864, towards the end of which year he made a survey in Italy, assisted in a survey for a proposed railway from Falmouth to St. Just, and was engaged in designing iron-roof work. In 1865 he went to Germany to continue his studies in mining, and afterwards designed the drill known by his name. He also superintended the execution of some deep borings for coal at Bokhold. In 1866 he took a contract at the Gelria Mine, in Westphalia, to drive a deep level by rock-drills, and put up air-compressing plant for the purpose; and in the following year he went to Cornwall, took contracts at Tincroft and Dolcoath Mines, and became well acquainted with Cornish mining. From 1867 to 1871 he was connected with the Siegena Sulphur Mine, as a Director and technical adviser, and with the Heidberg and Westphalia Silver-lead Mines. In 1871 he erected large sugar works in Egypt for the Khedive. From 1873 to 1878 he was Manager of the Welsh Main Colliery, and afterwards went to Bavaria, as Sub-Manager of the lead mine at Freihund. In 1880 he took a contract to work the Cae Cock Pyrites Mine in North Wales; and in 1881–1882 he was engaged for Messrs. Fawcett, Preston and Co. in designing air-compressing and other mining machinery, and in superintending the erection of the machinery and designing the dressing works at the La Reyna Mine in Spain. In 1883 he designed the air-compressing machinery for the Forth Bridge works, and a timber pier and large storehouses for the American Boghead Mining Company. From 1884 to 1888 he practised as a Mining and Consulting Engineer, reporting on mines in Spain, Portugal, Galicia, Germany, Mexico, England, Wales, and the Gold Coast of Africa, and for some months was Manager of the Akankoo Gold Mine. In 1888 he was engaged by Messrs. Fawcett, Preston and Co., in making experiments in evaporating fluids. He subsequently held for some years the post of General Manager of the Argentine Concessions Limited Gold Mine.

Mr. Doering died at Bad-Nauheim, Germany, on the 25th August, 1899, at the age of sixty-one.

He was elected a Member of the Institution on the 7th December, 1897.

JOHN DONALDSON was born at Elgin on the 29th December, 1841. His father and grandfather were large coach-builders and proprietors, running the principal lines of coaches from Aberdeen to the north of Scotland. When the subject of this notice was only three his father died, and his mother, owing to legal complications, being in somewhat straitened circumstances, removed to Aberdeen in order to send him to the Old Grammar School, where he was well grounded in the Scottish "Latinity." He lived in Aberdeen till he was fifteen, when he went to Tyneside to serve his apprenticeship with Mr. Robert Morrison, Marine Engineer, on the Ouseburn, Newcastle. Here he served six years, and for a long time was an enthusiastic volunteer, being present at the Queen's Edinburgh Review in 1860. Towards the end of his apprenticeship he gave this up in order to devote his spare time to mathematics.

After about eighteen months' drawing office experience with the Walker Iron Works and other firms, Mr. Donaldson, at the age of twenty-three, went as Chief Draughtsman to Messrs. Cowans, Sheldon & Co., a well-known firm of General Engineers and Crane Makers in Carlisle. But he saw that in order to rise in the profession he must obtain greater theoretical knowledge. He decided, therefore, to sell a small property in Aberdeen to provide the necessary funds for a course at Glasgow University, and wrote to Professor Rankine, who, finding him already well grounded, induced the Senate to allow him to take the course in one year (1866–67) instead of the usual two years. From the letters and certificates of the professors it appears that his Glasgow career was decidedly brilliant. Both Rankine and Sir William Thomson (Lord Kelvin) spoke of him as a most distinguished student. In the engineering class he was first in his year, and gained the first Walker prize for the oral examination given by the votes of the class, of which he was censor. In the natural philosophy class his fellow students awarded him a similar honour for "general eminence in the business of the class," while Sir William Thomson awarded him a prize for his work in the laboratory, which was chiefly in connection with torsional rigidity. Mr. Donaldson studied mathematics under Professor Blackburn and privately with Professor Everett, who was much struck with his ability for grasping mathematical ideas and the rapid progress he made. As it also appears that he studied very successfully analytical chemistry, geology and botany, it will be seen that he had great capacity for hard work,

a capacity which struck his future partner Mr. Thornycroft, whom he first met as a fellow-student at Glasgow.

After leaving Glasgow he went to sea for experience, and proceeded round the Cape to Suez in a small ship 120 feet long— a most adventurous voyage. While waiting at Suez for an expected appointment he served as Engineer in the Viceroy of India's Yacht, and was present with the fleet at Annesley Bay during Lord Napier's Abyssinian Expedition of 1868; and, on the appointment being offered, he was unable to accept it, as he was not allowed to leave the service during war time. Returning to England after the war he obtained the post of Chief Mechanical Engineer at the Dum Dum Ammunition Factory in India. His ability was there quickly recognised, and in addition to his work in connection with the factory, he was frequently consulted by, and working for, other Government Departments around Calcutta, among other things being the renovating of the machinery at Fort William Arsenal, for which he received the official thanks of the Director-General of Ordnance for India. He was now brought to the notice of Lord Mayo, the Viceroy, who was much struck by the administrative ability as well as the engineering skill he had shown at Dum Dum. At Lord Mayo's personal request Mr. Donaldson was transferred to the Public Works Department, and under his instructions proceeded up country into the Hazaribagh District to report on the advisability of the Indian Government undertaking the manufacture of iron, and, if found advisable, on the best methods to adopt. Mr. Donaldson's report was in favour of organizing the native smelters with a view to manufacturing small articles such as bolts, large sleeper nails, etc., in their own forges, at the same time erecting works for larger manufactures. He also presented estimates of the cost, and although his schemes appear to have been favourably received, they were not adopted at the time, as the Government had not the requisite money, but the reports were carefully considered when the manufacture of iron was taken up a few years later. In 1871 he became assistant to the Chief Engineer of the Calcutta Port Trust Commissioners, the late Mr. W. Duff Bruce, and was engaged in the construction of jetties on the embankment of the Hooghli, in the erection of cranes, etc., and it is said that he was considered by contractors a most zealous and hard-hearted official.

Mr. Donaldson married early in 1872 Frances Sarah, daughter of Thomas and Mary Thornycroft, both distinguished sculptors; and, as his wife's health suffered from the Indian climate, he

gave up, to the great regret of his friends, his promising Indian career, and came home to join his brother-in-law, Mr. Thornycroft. At that time Mr. Thornycroft had already built the fast river launch "Miranda," which marked a great advance in marine engineering. While his partner, as was natural, continued to dominate the scientific side of the business, Mr. Donaldson, in addition to managing the commercial side, rendered much assistance with his engineering skill and experience in manufacture. Though he can only be credited with a few minor inventions, he was always adding those touches which go to make success, evolving formulas, and introducing scientific methods of design. He also superintended the trials of many of the vessels built by the firm, and never failed to obtain the contract speed.

In 1873 the firm produced under the auspices of Admiral Koren and the Norwegian Government, the first fast torpedo boat, and Mr. Donaldson at once began to induce the European Governments to introduce the torpedo boat into their navies, contributing not a little to this end by his lecture before the United Service Institution in 1877,[1] which made considerable stir in naval circles. This was followed by his second paper in 1881,[2] and by the great increase of torpedo-boat armaments during the eighties, especially in this country.

When about the year 1885 Mr. Thornycroft brought out his well-known water-tube boiler, Mr. Donaldson at once saw the far-reaching consequences of its success, though from others it encountered at first opposition.

During the last few years of his life he was busy devising a form of protected destroyer to obviate the disastrous effect of gunfire upon unprotected vessels using high-pressure steam. The principal features were a very deep vessel of fairly high speed with submerged torpedo tubes and a protective deck. The centre of gravity was kept below the centre of buoyancy, so that in case the protective deck, under which there was plenty of surplus buoyancy, became flooded, the vessel would not lose her stability.

During the quarter of a century he was in the business, Mr. Donaldson's relations with the Trade Unions were on the whole very friendly. The works consisted largely of strong Union shops, owing to the high class of work, and the impossibility, in early days, of obtaining good workmen elsewhere. When in 1897 the engineers of the Amalgamated Society struck at Thornycroft's

[1] Journal of the Royal United Service Institution, vol. xxi. p. 611.
[2] *Ibid*, vol. xxv. p. 887.

and two other London shops, Messrs. Thornycroft at once filled their places with non-unionists, and Mr. Donaldson became a prime mover in forming the London Association of Engineering Employers, of which he was Vice-President when he died. He advocated strongly their joining the Northern Federation, and was one of the first two London representatives on the Federation Board. He attended all their meetings during this disastrous strike, and was appointed one of the fourteen delegates of the conference at Westminster. The work entailed by this strike led largely to the breakdown of his health.

Mr. Donaldson was for nine years a member of the Chiswick Local Board, and as Chairman of the Drainage Committee carried through the large scheme of drainage now in operation.

The subject of this memoir was a man of considerable cultivation, and was well read, indeed far more so than many whose early path in life was smoother. His interests were wide; a keen sportsman with rod or gun, and fond of yachting; he also found great pleasure in history, antiquities and art. Genial, generous and upright, of even temper and courteous manner, with a keen sense of humour, he was esteemed and respected by all who came in contact with him, while though somewhat retiring, his strong personality gave him facility in the "engineering of men." A man of much above the average physique he never spared himself, and the hard work of his early years, together with that entailed in building up, on sound principles, a business employing (in 1897) 1,800 men, undermined his health, and he died on the 4th October, 1899, after an illness of ten months, during which his cheery courage, though much tried, never failed. He left a widow with five sons and five daughters.

Mr. Donaldson was elected an Associate Member of the Institution on the 7th December, 1875, and was transferred to the class of Members on the 4th December, 1877. He was also a Member of the Physical Society, the Institution of Mechanical Engineers and the Institution of Naval Architects.

HORTENSIUS HUXHAM, born on the 10th December, 1830, was articled, in August, 1848, to the late Mr. William Southern Clark, Chief Engineer to the Marquis of Bute's estates in Wales, and was afterwards engaged with him as an Assistant on various works on the estate, and as Resident Engineer in sinking a trial pit at Cwmsaerbryn to prove the existence of steam coal in the

Rhondda district, prior to the construction of the Taff Vale Railway Company's branch up those valleys. He was subsequently engaged as Resident Engineer in carrying out the works for winning and establishing the Bute Merthyr Colliery on the site of the said trial pit; and the colliery having been leased, he remained as Engineer until 1858. From the latter date until 1862 Mr. Huxham practised in the Rhondda district, and, among other matters, as Engineer and part-owner, executed the works in winning and establishing the Abergorkie Colliery.

On the sale of that colliery Mr. Huxham removed to Swansea, and from that time practised in that town and district. Among the works with which he was connected may be mentioned the winning and developing of the Rhondda Mountain Colliery, the Bishwell Collieries, the Baglan Collieries, the Rhosamman Colliery, the Lower Resolven Colliery, and new deep pits in the Vale of Neath. He acted as Consulting Engineer to several collieries, was Joint Engineer with Mr. Joseph Kincaid for the Swansea Improvements and Tramways incorporated in 1874, and held the post of Secretary to the South Wales Institute of Engineers since 1871. He was also Secretary to the Western District Board of the South Wales Coal Owners Association, and Honorary Secretary at Swansea to the Royal Institution of South Wales.

Mr. Huxham died at his residence, 70 Bryn Road, Swansea, on the 17th February, 1900. As an engineer he had considerable experience of mining; and, while as a man he was retiring in disposition, almost to being reserved, he was always ready to help the younger members of the profession by advice and information. He contributed several Papers to the Proceedings of the South Wales Institute of Engineers.[1]

He was elected a Member of the Institution on the 11th May, 1875.

WARWICK HUSON JOHNSON was born on the 7th February, 1846. He went to India at the age of sixteen, and received his engineering training at the Thomason Civil Engineering College, Roorkee, where he qualified for the post of an Assistant Engineer in the Indian Public Works Department. He was appointed to that Department in 1865, and served in the Punjab provincial

[1] Proceedings South Wales Institute of Engineers, vol. i. p. 163; vol. ix. p. 201; vol. xi. p. 85; vol. xii. pp. 100, 191, 416; vol. xiv. p. 33; vol. xix. p. 108; vol. xx. p. 384.

branch from that year until 1872, when he was posted to the Military Works branch. From November, 1873, to May, 1875, he was employed on famine works in Bengal, and received the commendation of the Bengal Government for his services. In 1879 Mr. Johnson was re-transferred to the Punjab, and he continued to be employed in that province until his death, which took place on the 24th July, 1899. He had attained the rank of Executive Engineer, 1st grade, in 1884, and officiated as Superintending Engineer in 1893. He was within two years of his retirement on pension, having nearly completed thirty-four years' service in the Indian Public Works Department.

During his service in the Punjab Mr. Johnson constructed two important girder-bridges over the Kurrum and Gambeyla rivers on the north-west frontier road, and from 1889 to 1892 he was employed on the construction of the Bandipur Gilgit road in Kashmir, for which he was specially commended by the British agent at Gilgit.

Mr. Johnson was elected an Associate of the Institution on the 4th December, 1877, was subsequently placed in the class of Associate Members, and was transferred to the class of Members on the 22nd January, 1884.

JOHN LANYON, eldest son of the late Sir Charles Lanyon, was born at Belfast on the 21st April, 1839, and received his education at the Broomsgrove School. He then served an apprenticeship in his father's office, and in 1860 became a partner in the firm, under the title of Lanyon, Lynn & Lanyon, Civil Engineers and Architects. On the dissolution of the partnership in the year 1872 Mr. Lanyon continued to carry on the business himself. Amongst other important works designed by him and carried out under his supervision were the Draperstown Railway, the Limavady and Dungiven Railway, the Cavehill and Whitewell Steam Tramway, the Portstewart Steam Tramway, the Ballymena water-supply and sewerage, the Lisburn water-supply, and the sewerage irrigation works for County Antrim Asylum. He also prepared the parliamentary plans, estimates, etc., for the Ballymoney and Ballycastle Railway, the Belfast, Holywood, and Bangor Railway Extension, the Broughshane Railway Redbay Extension, the Killyleagh, Killinchy, and Comber Steam Tramway, the Tyrone Steam Tramways, County Antrim Coast Light Railway, Clandeboye and Helen's Bay water-supply and sewerage

(for the Marquess of Dufferin and Ava), and the Belfast City Central Station and Railways. This latter scheme was one for connecting, by means of tunnels, the three lines having termini in Belfast—the Belfast and Northern Counties, the Great Northern Railway of Ireland, and the Belfast and County Down Railway, the latter section to be brought under the River Lagan. Mr. Lanyon was highly complimented on this scheme by the Chairman of the Examining Committee of the House of Lords, but the Bill was unfortunately thrown out on a financial point, and on account of Mr. Lanyon's failing health the matter dropped. At the time of his death he was engaged on the plans for sewerage works for the town of Lisburn, and for gravitation water-supply for the County Antrim Lunatic Asylum.

Mr. Lanyon was an authority in Ireland on water rights, and the compulsory purchase of lands for water, sewerage, railway, town improvements, and such works, and had a large practice in this connection, both as arbitrator and as witness. For many years he was the official valuator to the Irish Civil Service Building Society, and the National Discount Company of Ireland. He had also a large practice as an Architect, and acted in that capacity for the Boards of the Belfast and Northern Counties Railway, the Great Northern Railway of Ireland, and the Belfast and County Down Railway; and amongst other important architectural works he designed and carried out were the Stewart Institution for Imbeciles at Dublin, Blarney Castle, Belfast Castle, the seat of the Earl of Shaftesbury, and County Antrim Lunatic Asylum.

Mr. Lanyon married a daughter of the late Mr. Edward Hyde, of Somerset House, and leaves two daughters. He died at Oratava, Teneriffe, on the 13th February, 1900.

He was elected a Member of the Institution on the 4th February, 1890.

ALEXANDER KENDALL MACKINNON was born at Monte Video on the 29th August, 1826. Coming to England at an early age, he received his preliminary education at Hoddesdon in Hertfordshire. From 1847 to 1849 he attended the engineering and architectural classes at University College, London, after which he was placed for a time with Mr. Thomas Page, under whom he was engaged on the construction of the Victoria and Albert Bridges over the Thames at Datchet, near Windsor. In 1852 Mr. Mackinnon was appointed Engineer to the Monte Video Gasworks,

which he entirely remodelled. Having completed that work, he proceeded in the following year to Buenos Aires, where he was placed by the Government on a Commission charged to examine and report on designs for a Custom House and for a railway from the capital to San José de Flores. He afterwards prepared plans for a railway from Monte Video to the town of La Union in connection with a scheme for a line from Monte Video to the Duragno, since carried out. In 1854 he was compelled by family matters to return to England, and for the following seven years he resided at Penzance, where, although he held no definite appointment, he practised from time to time as a Mining Engineer.

In 1863 Mr. Mackinnon again went to Uruguay, where he was employed by the Municipality of Monte Video on various road improvements. Three years later he was appointed Director General of Public Works, and in that capacity one of his first actions was to induce the Government of Uruguay to make obligatory the use of the theodolite in all surveying operations instead of the compass. A geodetic survey of the country was then carried out. In addition to advising as to railways and telegraphs, he was responsible for the design and construction of the London and River Plate Bank House, the lazaretto on the island of Flores, a new Custom House, a sea-wall for the improvement of the Port of Monte Video, and other public works. He was sent to England by the Government with special powers to raise a loan of £3,500,000, and to make contracts for the ironwork of the new Custom House, in both of which undertakings he was successful. He assisted in the formation of the North Western of Uruguay Railway Company and in the construction of part of that line, as well as in the laying of the Telegraph Cable from Monte Video to Chuy on the frontier of Brazil, since absorbed by the Western and Brazilian Telegraph Cables. He also rendered considerable assistance in the formation and subsequent reorganization of the Central Uruguay Railway Company. In 1887 he was appointed Consul for Uruguay, and in the following year he presented to the Government further plans for the improvement of the Harbour of Monte Video. He was for some years Chairman of the Monte Video Gas Company.

Mr. Mackinnon died at his residence, 12 Fopstone Road, Earl's Court, on the 19th February, 1900.

He was elected a Member of the Institution on the 5th April, 1870.

JOHN NAPIER, second son of the late Mr. Robert Napier, of West Shandon, the well-known engineer and shipbuilder, was born in Glasgow on the 18th June, 1823. He was educated first at the High School of Glasgow, where he gained the mathematical gold medal, and subsequently at the University. In 1839 he entered his father's business, and at the Vulcan Foundry was trained as an engineer under the late Mr. David Elder. In 1845 he designed the machinery for the Admiralty yacht "Fire Queen." The engines were quick-running with light pistons, and the framing was of malleable iron—a departure from the recognised practice. The vessel was a great success, attaining what was then a phenomenal speed of nearly 16 miles an hour. In 1852 Mr. Robert Napier associated with him in business his sons under the style of R. Napier and Sons, and in 1857, after the retirement of his brother, Mr. John Napier became the active partner, a position he retained until his withdrawal from business. During his management he was assisted by several well-known engineers, whom he appointed as works managers, among whom may be mentioned the late Sir W. Pearce, Mr. Walter Brock, Mr. Alex. Shanks, and Mr. J. W. Shepherd.

While under his direction, Messrs. Napier executed many large and important contracts for the British, French, Russian, Turkish, and other Governments. Among the special vessels may be noted the British ironclads, "Black Prince," "Hector," "Hotspur," "Audacious," "Malabar" and "Northampton," and the Turkish frigates. The connection formed by Mr. Robert Napier with the Cunard Company was continued, and in 1861 the "Scotia" was built, which at the time was the largest mercantile steamer afloat (excepting the "Great Eastern"), and long continued to be the "Queen of the Cunard fleet." In addition to building steamers for most of the leading lines, such as the Royal Mail Company, the Pacific Company, the Peninsular and Oriental Company, Mr. Napier took a special interest in the inception of Messrs. Currie's Cape steamers, designing for them in 1871 the "Edinburgh Castle" and the "Windsor Castle," which were followed by several other vessels each surpassing its predecessor.

In 1877, after the death of his father, Mr. Napier resolved to retire from business, and shortly afterwards took up his residence in London. He became a Director of Messrs. Donald Currie and Company, thus finding a congenial sphere for his leisure, and his engineering experience being much appreciated by his co-directors. Mr. Napier died in London on the 28th December, 1899. This notice would be incomplete without recording his unbounded gene-

rosity and kindly nature. He was always ready to help forward any good work, and none of his old employees was allowed to suffer in person from poverty. His anxiety on their account was beyond expression, and though it was 23 years since his retirement from business, up to the last they were the constant participators of his kindness.

He was since 1877 a Fellow of the Royal Society of Edinburgh, and he was also a member of numerous scientific societies.

He was elected a Member of the Institution on the 5th December, 1876.

SAMUEL USSHER ROBERTS, C.B., eldest son of Mr. Edward Roberts, J.P., of Weston, near Waterford, was born on the 21st May, 1821. He was a member of a Waterford family, distinguished in arts and arms, and a cousin of Field-Marshal Lord Roberts. After being educated at Burney's Royal Academy, Gosport, where he laid a good mathematical foundation for his future career, he served a pupilage under Mr. Kearney, Civil Engineer, on the expiration of which he was for two years occupied on his own account in the execution of works in Waterford, Carrick and Dungarvan. He was then for three years District Surveyor for County Louth, carrying on extensive arterial drainage works for the Commissioners of Public Works in Ireland. During the latter period, in 1847, he contributed to the Institution of Civil Engineers of Ireland, of which he was a Member, a valuable Paper on "The Means Adopted for Unwatering Works of River Drainage,"[1] describing, among other methods, his successful application of the turbine, worked by the head from the river turned into the "back drain," as the motive power for pumps in unwatering the channel excavation of the River Glyde.

Early in 1848, when only in his twenty-seventh year, Mr. Roberts was promoted to the charge of the district of Loughs Corrib, Mask and Carra, one of the two most important of the districts, numbering nearly two hundred, of which the works were then in progress or projected, under the Drainage Commission of the Board of Public Works in Ireland. This large district having a catchment area of 1,218 square miles, included the chain of three lakes of which the two chief, Corrib and Mask, contain respectively 68 and 34 square miles, stretching—roughly north-east—into the counties of Galway and Mayo, from the neighbourhood of the

[1] Transactions Institution Civil Engineers of Ireland, vol. iii. p. 1.

town of Galway, through which the short but broad and rapid River Corrib discharges the waters of the great catchment into the head of Galway Bay. The works, which involved an expenditure of about £200,000, comprised improvement of the drainage of Lough Corrib and its river tributaries, also opening a lock canal from the Port of Galway to the deep water of Lough Corrib; improving the navigation of the latter, and connecting it by a lock canal with Lough Mask; also improvement of the extensive mill-power of the River Corrib, in and near the town of Galway. These objects were successfully carried out, excepting the full completion of the Lough Mask canal, which unfortunately was prevented by financial considerations, after the pressure for distress relief works had slackened.

In and near the town of Galway the works were of a specially difficult and varied character, and included—besides the objects already specified—arrangements for the improvement of the important salmon fishery. The canal from Galway Bay to Lough Corrib was opened by, and named after, the Earl of Eglinton, Lord-Lieutenant of Ireland, in 1852.

The numerous interests of land proprietors, farmers, and mill and fishery owners, in such an extensive district, made it very much a case of "engineering men as well as matter"; but Mr. Roberts' skill, energy and tact, proved amply equal to both, and in the only two cases of lawsuits brought—by a fishery and mill owner respectively—the verdicts were in the Commissioners' favour.

After the completion of the Lough Corrib works Mr. Roberts acted under the Board as Consulting and Inspecting Engineer of important drainage schemes in other parts of Ireland, and in 1873 he was appointed a Member of the Board.

In 1887, among the Jubilee honours, Mr. Roberts was created a Companion of the Order of the Bath.

In 1891 he retired from his Commissionership, on pension, under the age order; but this did not close his career of active work, as he then became Consulting Engineer and Architect to the Lunatic Asylums Board, and the Congested Districts Board also had the benefit of his long experience. Besides his official duties Mr. Roberts' public spirit made him a highly-valued member of the Royal Dublin Society—long established for promotion of arts, sciences and agriculture in Ireland. As one of the Vice-Presidents he took a prominent part, especially on the Committee of Agriculture, on which his knowledge of horses made him one of the chief organisers and judges at the well-known horse show held annually at Dublin by the Society.

Bright and active to within a few days of the end, he died in Dublin after a short illness on the 11th January, 1900. His sterling and genial character caused him to be mourned not only by his family, but by many friends; while his marked ability, firmness and judgment, made him greatly missed as a public man. Mr. Roberts was married to Emily, eldest daughter of the late Sir George Forster, Bart., of Coolderry, Co. Monaghan, who survives him.

He was elected a Member of the Institution on the 7th March, 1854.

MURRELL ROBINSON ROBINSON was born on the 20th August, 1821. As a young man he was engaged for about three years on the Ordnance Survey, and was subsequently employed for a time on the Great Western Railway. In 1843 he became Secretary to General Moody, then Governor of the Falkland Islands, and three years later he was appointed Deputy Surveyor-General to the Government of Cape Colony, which post he held for ten years. He then had charge for two years of the whole of the Public Works of the Colony; was subsequently for four years Deputy Colonial Engineer and Commissioner of Roads, and in 1863 was appointed Chief Inspector of Public Works.

Between 1848 and 1850 Mr. Robinson rendered special services on the Eastern Frontier when employed by Sir Harry Smith in distributing land to Dutch farmers at a time of great excitement after the engagement of Boom Plaats in the divisions of Aliwal North and Dordrecht. He was again selected by Sir George Cathcart to devise and carry out in 1852–54 a scheme for the occupation of territory recently taken from the Tamboukis. Mr. Robinson superintended, during his term of office as Chief Inspector of Public Works, the construction of many important roads, light-houses, piers and bridges, of which that over the Great Fish River may be mentioned. In 1876, after thirty years' service, he retired on pension and returned to England. He died at his residence, 95 Philbeach Gardens, S.W., on the 25th January, 1900, in the 79th year of his age. Mr. Robinson married in 1850 Mary Anne, youngest daughter of Mr. John Bardwell Ebden, one of the earliest British settlers in the Colony.

He was elected an Associate of the Institution on the 28th May, 1861, and was transferred to the class of Members on the 24th May, 1870.

THOMAS GIBSON, born at Earsdon, Northumberland, in 1843, commenced his career in the office of Messrs. Saunders and Mitchell, of Westminster. While with that firm he was employed on the construction of the Madras Pier and other screw-pile structures. On returning from Madras he assisted his father in several screw-pile and screw-mooring contracts for the London and other docks and various harbours in the United Kingdom until the year 1867, when he was engaged by Messrs. McClean and Stileman for work on the Furness Railway. In 1869 he was appointed Resident Engineer under the late Sir Thomas Bouch on the Redheugh Bridge, Newcastle-on-Tyne, on the completion of which he returned to Furness. In 1874 he was instructed by Mr. (now Sir George) Bruce, Past-President, to superintend the erection of the Rio Tinto Company's pier at Huelva, Spain, on which work he read a Paper before the Institution.[1] After a short stay in England he returned to Spain on the Seville and Huelva Railway, having charge of the bridgework, which included a five-span bridge carried on cylinder piers over the Guadalquiver at Seville, beside eleven other structures over the waterways along the line.

On his return to England he went into business for himself, carrying out several contracts, among which may be mentioned the foundations for G and H warehouses in Victoria Dock, the underpinning and straightening of the walls and clock-tower of the Town Hall, Great Yarmouth—a description of which by Mr. F. E. Duckham appeared in the Proceedings of the Institution[2]—and the erection of a 230-foot span bridge for the Rio Tinto Railway Company at Salamon, of a bridge over the River Lea for the Carpenters' Company, and of coal viaducts for the Gas Light and Coke Company at Beckton. His last contract was for life-boat slipways at Margate for the Royal National Life-boat Institution, in the carrying out of which he was caused much worry and anxiety owing to the gales of the winter of 1897 sweeping away the staging and temporary works on two occasions. His health was thoroughly undermined, and diabetic symptoms began to appear which rapidly took a virulent form and from which he died on the 11th June, 1899.

He was elected an Associate of the Institution on the 5th May, 1868, and was subsequently placed in the class of Associate Members.

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[1] Minutes of Proceedings Inst. C.E., vol. liii. p. 130.

[2] *Ibid*, vol. xcviii. p. 372.

THOMAS ELCOAT LAING, born on the 14th September, 1848, passed through the engineering course at Owens College, Manchester, and subsequently served articles for three years with Mr. Edgar Gilkes, Engineer, of Middlesbrough. In 1870 he entered the service of the Middlesbrough Corporation as Assistant Engineer on municipal works. Between 1873 and 1878 he carried out for a company of Belgian concessionaires large waterworks at Hof, in Bavaria, and at Schwarzenberg, in Saxony, on the completion of which he was elected a Member of the German Association of Engineers and Architects. He returned to England in 1878, entered the service of the Wolverhampton Corporation as Assistant Engineer, and subsequently obtained a similar appointment under the Salford Corporation, where he was engaged on the carrying out of extensive sewerage works, main drainage, bridge and tramways, under the late Mr. Arthur Jacob. In 1882 he entered the service of the Leicester Corporation as Assistant Engineer for the extensive flood prevention and navigation works at Leicester, on which he was engaged under the late Mr. Joseph Gordon. He was also employed on the sewerage and main drainage works of that town. From July, 1892, until the end of 1894 Mr. Laing acted as a District Surveyor under the Corporation of Sheffield. Early in 1894 he proceeded to West Africa to take up the appointment of Director of Public Works for Sierra Leone, which post he held for nearly five years. Mr. Laing died of fever at Freetown on the 19th November, 1899.

He was elected an Associate Member of the Institution on the 20th May, 1890.

THOMAS ROBERTS, son of the late Mr. Griffith Roberts, of Coedisaf, was born at Dyffryn Ardudwy, Merionethshire, on the 17th February, 1837. He commenced his professional career in the office of Mr. J. Y. Robins, Civil Engineer, of Birmingham, in 1859, and in 1866 he began to practise on his own account at Portmadoc. During the thirty-four years of his residence in that town he designed and executed numerous works in the Festiniog slate quarries, such as tramways, inclines, reservoirs, slate converting machinery, etc., for Mr. Samuel Holland, M.P., and others; made Parliamentary plans and sections for the proposed North Wales narrow gauge railway; surveyed, set out, and prepared a working section of the Merionethshire Railway; made a Parliamentary survey for the Bala and Festiniog Railway; designed and executed

works of water-supply for Dolgelly and sewerage works for Portmadoc; assisted Mr. George Owen in connection with the extension of the Cambrian Railway to Porthdinlleyn; designed inclines and a large pile pier at Portnant, Carnarvon, for the Cambrian Granite Company; prepared Parliamentary plans, and acted as Engineer for the Portmadoc water scheme for the extension of works to supply the towns of Portmadoc, Penrhyn, Borth, and Tremadoc; and designed and executed works of water-supply for the towns of Barmouth, Pwllheli, Bala, Festiniog, and the Rural Sanitary Authority of Llanrwst, and sewerage works for Portmadoc, Barmouth, Pwllheli, Nevin, Trefrew, Dolyddelen, and Penmachno. His services were frequently in demand in arbitration cases affecting rights of property, and for many years he acted in the capacity of Engineer to the Tremadoc estate.

Mr. Roberts died at Portmadoc on the 13th January, 1900.

He was elected an Associate Member of the Institution on the 31st May, 1881.

FREDERICK WILLIAM SLAUGHTER, born at Brixton on the 16th December, 1863, was educated at Vale Academy, Ramsgate, and at the City Guilds Technical College. He served an apprenticeship to Messrs. J. & G. Rennie, of Blackfriars, afterwards gaining some experience as a sea-going engineer for one year on board the s.s. "Plymothian." In the year 1885 he was engaged as a draughtsman at Messrs. Stones' Brass and Iron Works, New Cross, on leaving which firm in 1891 he obtained the post of Chief Assistant to Mr. W. T. Douglass, under whom he was engaged in designing lighthouses, optical apparatus, fog-signals, life-boat launching slips, bridges, etc. In June 1899 he proceeded to Calcutta. His death took place on the 28th December following, from enteric fever.

Mr. Slaughter was elected an Associate Member of the Institution on the 6th December, 1892.

NOWROSJEE NESSERWANJEE WADIA, C.I.E., died at Boscombe, Bournemouth, on the 19th December, 1899, at the age of 50. Born at Bombay in 1849, Mr. Wadia was educated in England, where he obtained some experience in the cotton mills of Lancashire. Returning to India he was employed under his father

in the erection of cotton mills and machinery, and was then entrusted with the management of the engineering department of the Albert Cotton Mills. While there his attention was turned towards the construction of machinery for paper-making, and he subsequently designed and erected several paper mills, his colossal engine for the Maneckjee Petit Mills attracting considerable attention. Mr. Wadia was largely instrumental in developing the cotton mill industry which has been so prominent a feature in Bombay during the past thirty years, and he also rendered valuable service to the cause of technical instruction in the Presidency. He acted as Honorary Secretary of the Victoria Technical Institute, he was one of the pioneers of hosiery and sewing-thread manufacture in India, and he established a dyeing manufactory at Mahim.

Mr. Wadia was appointed by Lord Reay a member of the Legislative Council, in the deliberations of which body his technical knowledge was of great value, and as a member of the Municipal Corporation he did much to improve the sanitary condition of Bombay. His benevolent disposition made him a munificent supporter of many charitable institutions, and in him the Parsee community in Bombay has lost a warm and generous friend. In recognition of his public services the Companionship of the Order of the Indian Empire was conferred on him.

Mr. Wadia was elected an Associate of the Institution on the 2nd December, 1873, and was subsequently placed in the class of Associate Members.

EDWARD CORRY, who died on the 12th January, 1900, at 62 Marina, St. Leonard's-on-Sea, was the last surviving son of the late Mr. James Corry, of Dublin. Born in 1817, the subject of this notice came to London about the year 1840, and was for some years engaged in the carriage-building department of the Great Western Railway Company. He was subsequently for five years manager, under Mr. William Brydges Adams, of the Fairfield Works at Bow, where a large business in the construction of railway carriages was carried on. About the year 1850 Mr. Corry began business on his own account in Old Broad Street as a Commission Agent and Iron and Copper Merchant. Among the firms for which he acted as London Agent were Messrs. Brown, Marshall and Company, Messrs. Lloyds, Foster and Company, and Messrs. Kitson and Company, while he represented Messrs. Dübs and

Company in London for thirty years. Mr. Corry retired from business in the spring of 1894. He was a man of spotless integrity, and exceptionally large-hearted.

Mr. Corry was an Associate of the Institution for upwards of forty years, having been elected on the 1st March, 1859.

GEORGE FURNESS was born on the 31st October, 1820, at Great Longstone, Derbyshire. At an early age he was apprenticed to a cutlery firm at Sheffield. Completing the apprenticeship in 1840 he left, and made his first venture in railway construction on the Thirsk branch of the North Eastern Railway, the Engineer being the late Mr. Thomas Elliot Harrison, Past-President. Subsequently Mr. Furness was engaged for four years on the construction of the line between Paris and Rouen under the late Mr. Thomas Brassey. He then returned to England and was employed on the Oxford and Banbury line, for which Mr. I. K. Brunel was Engineer. In 1849, on the completion of the Oxford and Banbury line, Mr. Furness undertook his first contract in London, the construction of the approaches to London Bridge Station, on which he was engaged for three years. In 1853–54 followed the building of the reservoirs and other works at the Crystal Palace under the direction of the late Sir Joseph Paxton, and the construction of the Caterham Railway. This line Mr. Furness worked for two years after its completion, and finally sold it to the South Eastern Railway Company. In 1855 two large contracts were entered into, the first being for the Recife, São Francisco and Pernambuco Railway, 78 miles in length, which took five years to construct. The engineering difficulties of this work were augmented by the unhealthy climate of the country through which the line was carried. The second contract, that for the Staines, Wokingham, Reading and Reigate line, the Engineer for which was the late Sir John Hawkshaw, Past-President, was completed in 1857. In the previous year Mr. Furness had constructed the Abingdon line, and commenced the Redditch line for the Midland Railway Company. In 1858 the West Somerset line, for which Mr. Brunel was Engineer, was undertaken. The year 1862, in which Mr. Furness undertook three large and interesting contracts, marked the beginning of a period of great activity. The first was for the Northern Outfall Sewer and Reservoirs of the Metropolitan Main Drainage, for which the Engineer was the late Sir Joseph Bazalgette, Past-President. The second was the

drainage and paving of the City of Odessa, which contract was entered into with a committee appointed by the Czar, and was to make good in many instances the damage caused during the bombardment in the Crimean War. The third contract was with the Italian Government for dredging the harbour of Spezia, on the completion of which Mr. Furness was decorated by King Victor Emanuel with the Order of the Crown of Italy (3rd class). In 1864 he undertook the contract for the construction of the Victoria Embankment between Westminster and Waterloo Bridges, and in 1868 that for dredging the Harbour of Leghorn, blasting rock banks, and the removal of an old breakwater for the Italian Government. This work lasted for a period of fourteen years. He also carried out for the Italian Government the work of dredging and removing rock banks in the Harbour of Ancona. Mr. Furness undertook his last railway contract in 1879, the Hundred of Hoo line, a branch of the South Eastern Railway to Port Victoria. In 1882 the Palermo dredging and rock removal contract was entered into with the Italian Government; the work occupied thirteen years, and was the last contract Mr. Furness undertook. It was on this work that he designed special plant for the drilling machinery and for the floats.

On retiring from the business of a contractor, Mr. Furness devoted his latter years to looking after and developing his property in and around Willesden, where he was well known and highly respected. He was the first Chairman of the Willesden Local Board, served as a member of the first Middlesex County Council, and was for many years a member of the Hendon Board of Guardians. Although in failing health for some months he attended to business until the end, and was in his office at Willesden as recently as the Tuesday before his death, which took place on the 9th January, 1900.

Mr. Furness was elected an Associate of the Institution on the 2nd February, 1864.

SIR JOHN GRAHAM McKERLIE, Colonel R.E. retired, K.C.B., died at his residence, 3 Longford Terrace, Monkstown, Dublin, on the 7th January, 1900. The eldest surviving son of the late Captain Robert McKerlie, of Wigton, the representative of an ancient Galloway family, he was born in 1815, and entered the Corps of Royal Engineers from the Royal Military Academy, Woolwich, in 1833. He was first stationed at Mauritius, where he remained for some years. There he married in 1841 Sophia Caroline, daughter

of the late Lieutenant-General Henry John Savage, R.E. On returning to England he was engaged on Ordnance Survey work successively at Chatham, Manchester and York. In 1855 he was appointed a Commissioner of the Board of Public Works in Ireland, and in 1864 he succeeded Sir Richard Griffiths as Chairman of that Board. In the following year he retired from the corps of Royal Engineers with the rank of Colonel. He was created a Companion of the Order of the Bath in 1870, and in 1883, on his retirement from the office of Chairman of the Irish Board of Works he was promoted to the rank of Knight Commander of that Order. Sir John McKerlie was devoted to his work and carried out the duties of his post with unwearying zeal, and in times of political and agrarian troubles even at personal risk. His unfailing courtesy and the kindly spirit he displayed to all who sought his advice and aid, gained for him the title of "the poor man's friend." He was an ardent sportsman, a painter and lover of art, and rendered much service as one of the Governors of the National Gallery of Ireland.

Sir John McKerlie was an Associate of this Institution for nearly forty-nine years, having been elected on the 21st January, 1851.

WILLIAM ELLIS METFORD was the elder son of William Metford, M.D., of Flook House, Taunton, by his marriage with Miss M. E. Anderdon, and was born on October 4th, 1824. He was educated at Sherborne, and afterwards became a pupil of Mr. W. M. Peniston, then Resident Engineer, under Mr. Brunel, on the Bristol and Exeter Railway, and from 1846 to 1850 was employed under Mr. Brunel on the Wilts, Somerset, and Weymouth Railway. He subsequently worked for Mr. T. E. Blackwell, in connection with schemes for developing the traffic of Bristol, and afterwards for a short time acted as engineer under Mr. Peniston, who was contractor for the Wycombe Railway.

During this period of his life he made many friends in the profession, and in 1855 became acquainted with Mr. William Froude, who at once recognized his ability and skill, and became his most intimate friend.

Mr. Metford devised a form of theodolite, with a traversing stage and a curved arm upholding the transit axis, which is described in the Proceedings of the Institution for February, 1856.[1]

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[1] Minutes of Proceedings Inst. C.E., vol. xv. p. 247.

He also invented an improved level, in which the upright stem of the level telescope terminated in a sphere resting on the lower plate of the level and gripped by a ring grip tightened by four screws pulling downwards, and having spherical nuts. The instrument could thus be adjusted accurately even if the plates were as much as 25° out of the horizontal. Mr. Froude suggested a further improvement—that the sphere should not rest on the bottom plate, but should have an internal hollow sphere resting upon a small sphere concentric with the outer sphere.

Early in 1857 Mr. Metford, who had married a daughter of Dr. Wallis of Bristol, obtained a very important appointment on the East Indian Railway under the present Sir Alexander Rendel. This he obtained largely through the recommendation of Mr. Blackwell and Mr. Brunel. He arrived at Monghyr, on the Ganges, in May of that year, the mutiny having just broken out. Here there was every probability of an outbreak; the town of 50,000 native inhabitants contained no troops but a handful of Sepoys belonging to a mutinied regiment. The Europeans, some seventy or eighty in all, were taking no active steps to organise defence. If they fled, as was possible by boat, the town would be given over to anarchy and violence. Mr. Metford decided to remain, and, with his railway staff, took in hand, as well as he could, the organization of patrols and other repressive measures. His task was difficult, for he had no official position as leader. The old fort was ruinous, and too large to be defended by so few; a house was accordingly fortified and provisioned in case of need. Patrols and guards were organised, and it became known that "Metford Sahib" was making explosive shells and other murderous inventions. Besides taking his turn of guard duty, he superintended every measure of defence, and could scarcely rest night or day. It was the most trying part of the Indian hot weather, and not until the beginning of August could English soldiers be spared to garrison the town. Had it not been for Mr. Metford's determination another massacre might have been added to the story of the Mutiny. The heroism of the man who prevented it has remained unrecognised and almost unknown.

The strain of this terrible time left him seriously ill—suffering from inflammation of the membrane lining the brain—and after some months of rest, and an attempt to resume his work at Monghyr, he returned home after little more than a year's absence from England, and was obliged definitely to abandon the profession. Much of the work which he afterwards accomplished was done under the strain of continual depression and headache.

He soon resumed his old hobby—experiment in rifle work. As early as 1852 Mr. Metford had carried on experiments at the long distance of 1,200 yards. About the end of that year he suggested a hollow-based bullet for the Enfield rifle, which was brought to the notice of the Committee on Small Arms in 1853 by Mr. Pritchett, and adopted by them. Both at this time and afterwards, he made many experiments on alloys of lead, tin and antimony, and on the changes in hardness which take place in them with time.

In 1854 he investigated the disturbance of the barrel by the shock of the explosion, which affects the line of flight of the bullet, a difficulty which had led to much misunderstanding. About this time he designed a form of telescopic sight, which he afterwards used a good deal, and which was a decided improvement on existing patterns.

He gave much attention to the problem of making an explosive rifle bullet, and in 1857 sent in his invention to the Select Committee, who found it the best of those offered to them. It was not adopted, however, until 1863, when it had successfully competed against Colonel Boxer's and General Jacob's shells. It was very cheap and easy to manufacture, the explosive being a mixture of sulphur with chlorate of potash, and the hollow a simple one at the nose of the bullet. The Convention of St. Petersburg in 1868 put an end to the use of explosive rifle bullets; but the superior accuracy of the hollow-fronted bullet led to its retention for the Service rifle.

The Volunteer movement of 1859–60 had led to a great revival of interest in rifle work, and at the Wimbledon meeting of 1862 Mr. Metford made the acquaintance of Sir Henry Halford, henceforward his friend and assistant in his experiments. Together they competed, with rifles specially designed by Mr. Metford, for the prizes given by the National Rifle Association in 1864–65 for shooting at 2,000 yards. In both these years Mr. Metford's rifles were successful. He now made many experiments to determine the velocity of the bullet at different points in its passage along the barrel, and was able to lay down a curve for such a spiral as would give the bullet equal increments of rotation in equal times—the only scientific basis for an increasing spiral. This invention, though it proved to be less important than was at first supposed, formed the subject of a patent. A new form of ballistic pendulum, with double suspension, suggested partly by Mr. Froude, was of great help to Mr. Metford in his experiments.

Mr. Metford's chief distinction in rifle progress, however, is, that

he was the pioneer of the substitution of very shallow grooving and a hardened cylindrical bullet expanding into it, for deep grooving and bullets made of soft lead. No one before him had realised that the expansion of a bullet under the blow of the powder was ample and instantaneous, and that deep grooving served to accumulate fouling, while soft lead created unnecessary friction. The Whitworth system of polygonal grooving gave far more grip on the bullet than was needed to give it a proper spin. Mr. Metford found that a bullet could be spun with rifling only 0·0005 inch deep, and that a depth of 0·004 inch was ample for all practical purposes. In 1865 his first match-rifle appeared, having five shallow grooves, and shooting a hardened bullet of special design. It immediately attained prominence in the hands of Sir Henry Halford, and in a very few years Mr. Metford's rifles, and those made on the same principles, had left all others far behind.

The Martini action, in combination with the Henry barrel, was adopted in February, 1869, by the Small Arms Committee, who had before them the work of all the prominent rifle-makers of the day, but not Mr. Metford's, and in 1870 he embarked seriously on the production of a breech-loading rifle. He saw that the solid-drawn brass cartridge-case was, for strength and simplicity, far ahead of the compound rolled case adopted for the Service; and that, considering the needs of hot climates and other practical conditions, lubrication of bullet or cartridge was inadmissible. Every detail of the barrel and cartridge received close attention, and especially the form of the chamber and of the "entry" conducting the bullet from the cartridge into the rifling. The adoption of a grooving of segmental form was also found to give great advantages in preventing the accumulation of fouling. It was not long before Mr. Metford's first experimental breech-loaders made their appearance, and at Wimbledon, in 1871, two rifles and a limited supply of home-made ammunition were used. With one of these Sir Henry Halford won the principal prize for military breech-loading rifles—a single prize of £50—given by H.R.H. the Duke of Cambridge, and shot for at 1,000 yards.

In 1872, a match, at Wimbledon, between teams armed with breech-loaders and muzzle-loaders, proved that, while the latter was certainly still superior, the Henry match breech-loader was quite out-classed by the Metford military rifle with match sights attached. By 1877 the rifle and ammunition had passed out of the experimental stage, and were made by makers of repute, to whom great credit is due for the good workmanship, which was an

indispensable condition of the success of the rifle. From that time the record of the military rifle is an unbroken series of triumphs; and in the whole twenty-three years up to 1894, when military rifles of larger bore than 0·315 were no longer recognised by the National Rifle Association, the Metford rifle only four times failed to win the Duke of Cambridge's prize, while it took a preponderating share of the other prizes. The Martini-Henry, adopted so recently by the Committee on Small Arms as the best breech-loader, soon found its level, and after 1882 absolutely disappears from the longe-range prize lists for the military breech-loader class. The superiority of the Metford rifle was notably shown in the matches with the military rifle between the Volunteers of Great Britain and the National Guard of the United States, in 1882 and 1883, when the American rifles proved to be decidedly inferior to the British, notably at the long ranges, and almost the whole of the British teams used the Metford rifle.

The rapid advance in military small arms abroad, especially as regards quickness of loading, caused the appointment of a Committee to deal with the question of an improved British rifle in February, 1883. Mr. Metford designed, at the request of the Committee, the detail of the barrel of 0·42 bore for the rifle provisionally issued for trial at the beginning of 1887. But just at this time the question of further reduction of the calibre was raised, as a result of Continental experiments, and the outcome was the adoption of the present 0·303 barrel and cartridge for the Service. Mr. Metford's unique knowledge enabled him at very short notice to lay down the proper proportions for the grooving, the pitch of the spiral, the shape and dimensions of the "entry," and the "clearances" to be given for the cartridge, all so satisfactorily, that though he himself verified them at much trouble and cost, and the Committee also tried them exhaustively, it was found that no modification could improve them, either as regards accuracy, convenience in use, or ease of manufacture. The 0·303 was first used with black powder, for which his segmental grooving was almost essential, and it was only the rapid destruction of the bore by the smokeless powder afterwards adopted which made it advisable to return to a very obvious form of grooving which had been used by Mr. Metford twenty-five years earlier. The adoption of the name Lee-Enfield for the 0·303 magazine rifle with the altered grooving obscures the fact that the shape of the groove was only one of many details connected with the barrel, chamber and cartridge, which are due to Mr. Metford's skill. The form of the bullet, for instance, is one which he found

to meet with less resistance from the air than any previously invented.

Rifle work was by no means the only subject in which Mr. Metford took an active interest. He was something of an astronomer; was an authority on the making of fireworks; and knew much about kite-flying. He studied thoroughly the questions involved in the cutting of precious stones, and at the Exhibition of 1862 showed some jewels beautifully cut by a mechanism of his own invention. He was an interested reader of books on many subjects.

A return, in 1892, of his old illness in an acute form put an end to Mr. Metford's active work, and after some years of failing health he died on October 14th, 1899. Those who knew him will always remember specially his kindness, his deep and genuine nature, his wide sympathies, his extreme accuracy of mind as well as of hand, and the untiring thoroughness of his work.

Mr. Metford was elected an Associate of the Institution on the 4th March, 1856.

WILLIAM PIPER, born on the 19th April, 1818, was educated at Mill Hill School. He obtained his business training under his father, the late Mr. Thomas Piper, builder and contractor, of Bishopsgate Street, and remained with the firm of Thomas Piper and Sons until 1853, from which year he carried on business by himself at Stangate, Lambeth. The first large Government contract he undertook was for the construction of huts for the troops in the Crimea. After that war his chief work was the erection of fortifications in the neighbourhood of Portsmouth. Mr. Piper retired from business about the year 1866. He died at his residence, Beechwood, Highgate, on the 7th February, 1900, in his 82nd year.

Mr. Piper was an Associate of the Institution for nearly fifty-one years, having been elected on the 3rd April, 1849.

_ The following deaths also have been made known since the 24th February, 1900:—

Members.

ANLEY, GEORGE AUGUSTUS D'AUVERGNE; *died* 16 February, 1900.

BRUCE, WILLIAM DUFF; *died* 24 April, 1900.

BRUFF, PETER SCHUYLER; *died* 24 February, 1900.

BRUNTON, GEORGE; *died* 28 March, 1900.

FIELD, ROGERS, B.A. (*London*); *died* 28 March, 1900.

HIGGINSON, HENRY PASLEY; *died* 26 February, 1900.

JACOMB-HOOD, ROBERT; *died* 10 May, 1900.

PRITCHARD, EDWARD; *died* 11 May, 1900.

SANDERS, RICHARD BARNSLEY, B.E. (*Royal*); *died* 13 February, 1900.

SHERRARD, ? JAMES CORRY; *died* 4 March, 1900.

STENT, WILLIAM KITSON; *died* 7 May, 1900.

STONE, CHARLES; *died* 20 April, 1900.

Associate Members.

HOLME, JOHN CARTMEL; *died* 3 February, 1900.

MÜLLER, HENRY ARTHUR CASPERSZ.

NUTTALL, THOMAS; *died* 6 May, 1900.

STEVENS, FREDERICK WILLIAM, C.I.E.; *died* 5 March, 1900.

STEWART, ALEXANDER; *died* March, 1900.

THOMPSON, JOHN (of Warrington); *died* 16 February, 1900.

Associates.

CROFTON, EDWARD, M.A. (*Oxon.*); *died* 12 March, 1900.

IZARD, FRANCIS HENRY; *died* 21 February, 1900.

JOHNSON, JOHN HENRY; *died* 12 March, 1900.

PEPPER, JOHN HENRY; *died* 29 March, 1900.

PIDGEON, DANIEL; *died* 13 March, 1900.

Information as to the career and characteristics of the above is solicited in aid of the preparation of Obituary Notices.—SEC. INST. C.E., 15 May, 1900.

Sect. III.

ABSTRACTS OF PAPERS IN SCIENTIFIC TRANSACTIONS AND PERIODICALS.

Ballasting of Railway Tracks. Schubert.

(Organ für die Fortschritte des Eisenbahnwesens, 1899, p. 118.)

Experiments made by the Author on a small scale a few years ago convinced him that on a clay formation the depth of ballast should not be less than 1 metre (3 feet $3\frac{3}{8}$ inches) below the top of the sleeper.

This conclusion has since been confirmed by observation of actual cases of railways laid on a clay foundation.

One of the illustrations in the original shows a part longitudinal section of a line in a clay cutting in which the permanent way had been originally laid with a depth of ballast of from 0·5 metre to 0·6 metre (1 foot 8 inches to 2 feet) under the sleepers. This, however, had not sufficed to prevent the clay from welling up in layers between the sleepers, which were laid at 0·8 metre (2 feet $7\frac{1}{2}$ inches) centres. A table of results of extensive tests of the durability of various ballasting materials is given.

Other investigations showed that hard broken stone ballast requires only one-sixth of the quantity and one-third of the labour necessary for gravel ballast.

Information was also obtained as to the process of deterioration of ballast under a sleeper by means of photographs of exposed sections (reproduced with the Paper); these showed how the ballast becomes pulverized and reduced to an impervious inelastic mass, the evil originating directly under the sleeper and gradually spreading downwards and outwards, causing the sleeper to ride on its centre, thus further bringing about pumping of the ends of the sleeper and general straining of the permanent way.

W. B.

Pine Sleepers for Railway Tracks. C. Bräuning.

(Organ für die Fortschritte des Eisenbahnwesens, 1899, p. 143.)

On the Prussian State Railways pine timber is now generally used in place of oak for sleepers, and the dog spikes formerly used have been abandoned in favour of screwed spikes.

On the track where the changes were first introduced pine

sleepers were substituted for oak, the other conditions remaining the same, namely, No. 2 or 3 dog spikes and 18-centimetre × 16-centimetre (7 inches × 6¼ inches) sole plates. Although the traffic did not amount to more than a million tons per annum, the pine sleepers soon showed signs of wear, the timber deteriorating in irregular patches under the sole plate, the gauge of the rails also requiring attention. The edges of the sole plates cut into the soft timber, splitting and crushing the fibres, while the ballast got in between the sole plate and sleeper, further destroying the timber and admitting the wet. Screwed spikes with clip plates and spring washers were first used on pine sleepers in 1891, the number being four at a rail joint and two elsewhere. With these it was found more difficult to lay the rails to a correct and uniform gauge than with plain spikes, but there was less subsequent movement. The improvement over the first method was decided, the closer and more rigid connection between the sole plate and the sleeper being the chief cause of this. It was also found that with the screw fastening the actual cubic content of the part of the sleeper worn away under the sole plate was less than with the plain spike by 50 per cent. In both cases the wear of the joint sleepers was 20 per cent. more than that of the intermediate ones. Other results obtained were that oak sleepers with plain dog spikes lost by wear only one-third the amount lost by pine sleepers with the same fastening, and that the absence of sole plates increased the wear 100 per cent.

The Author concludes from his observations, and from theoretical considerations, that the usual flat wrought-iron sole plate is not sufficient to hold the rail upright, and recommends deep cast-iron chairs with four screwed spikes and two bolts for the rail.

W. B.

Metal Sleepers. AUGUSTE MOREAU.

(Mémoires de la Société des Ingénieurs Civils de France, Nov. 1899, pp. 672–689.)

Estimating that the railways of the world are equivalent at the present time to 560,000 miles of single line, carried on more than 1,000 millions of sleepers, which cost annually £16,800,000 for maintenance and redemption, the Author points out that an annual saving of only 2 per cent., or one-tenth of a penny per sleeper, would represent a reduction of £336,000 per annum. In 1881 methodical trials of eleven kinds of iron and steel sleepers were commenced on the Netherlands State Railways by their engineer, Mr. J. W. Post; and from 1881 to 1890 twenty trial lengths of line were laid down, embodying successively the latest improvements in sleepers and rail fastenings, which were represented by eleven different patterns. During the 17 years 1882–1898 these several trial lengths were carefully watched by Mr.

Ch. Renson, the engineer who had charge of them, in comparison with a length of line laid in 1881 with new sleepers of good oak on the plan then in use; and he drew up a report [1] of the results of his observations, from which the Author has derived most of the information here given.

Of the metal sleepers, some were made of thicker section in certain portions of their length, with the object of increasing their strength in these portions, while others were of uniform section throughout their whole length; all were either rolled in trough shape, or rolled flat and afterwards dished in a mould into trough shape. The conditions under which the trial lengths were laid were those obtaining on nine-tenths of the railways in Europe: ballast of sand and gravel; sleepers 3 feet apart, centre to centre; steel rails weighing 76 lbs. per yard; angle-bar fish-plates; 68-ton locomotives, with 13·9 tons greatest load on any one axle; highest speed 47 miles an hour; fourteen to twenty-nine trains a day; ruling gradient 1 in 62, or 16 per 1,000; sharpest curves 17 chains radius. The plan which gave the best results was one of those devised by Mr. Post, called the "dromedary": steel sleeper, length $8\frac{1}{2}$ feet for the 4 feet $8\frac{1}{2}$ inches gauge, width over flanges 5 inches to $5\frac{1}{2}$ inches in middle and $9\frac{1}{4}$ inches under rails, depth $4\frac{1}{2}$ inches in middle and 3 inches under rails; metal thickened to $\frac{7}{16}$ inch under rails; two round bolt-holes drilled at each rail for $\frac{7}{8}$-inch bolts, which are put in from below, and are prevented from turning by their square heads being held between two $\frac{3}{8}$-inch longitudinal ribs rolled on the underside of the flat top or table of the sleeper. This plan is considered by Mr. Renson to be far superior to oak sleepers in all respects: durability, cost of renewing sleepers and rail fastenings, preservation of sole of rails, safety, and cost of ordinary maintenance; the last includes packing up, straightening the line, trueing the gauge, and ballasting.

How well metal sleepers in ordinary ballast can withstand rust is shown by the fact that 10,000 Cosijns iron sleepers of ⊢⊣ section, with oak blocks under the rails, were laid in 1865 on the Netherlands line between Deventer and Olst in Overyssel, and are now in good condition after thirty-four years' service, during which more than 200,000 trains have run over them; they are expected still to last so much longer that the oak blocks are now being replaced by metal blocks. The fastenings also, including the screw threads of bolts and nuts, so far withstand rust that the yearly cost of renewals is less than for the fastenings used with oak sleepers.

Wear of sleepers and rails is largely dependent upon their being fastened securely to each other. Having tried various plans of bolts and nuts, Mr. Renson has found that some of them are perfectly secure against getting loose under the vibrations pro-

[1] Published in 1898 in the Bulletin International du Congrès des Chemins de fer.

duced by trains; and that in these instances the wear of the sole of the rails, of the top of the sleepers, and of the bolt-holes, bolts, and washers, is reduced to a minimum. His experience is confirmed by that obtained on the St. Gothard Railway, on which steel sleepers of the Post pattern have been used almost exclusively from 1886; their durability is considered to be equal to that of the steel rails, and therefore several times greater than that of oak sleepers. For heavy traffic, and especially on curves, he recommends interposing an iron or steel plate between the sleeper and rail, to take the wear; it can be renewed at any time without taking out the bolts securing the rail to the sleeper. On the Eastern Railway of France a trial length was laid in 1886 with steel sleepers of Post pattern, 2 feet apart, carrying 60-lb. rails; these sleepers had no longitudinal ribs on the underside of their flat top, and were not narrowed in the middle; a pad of felt was interposed between the sleeper and the sole of the rail, which prevents any friction between them, keeps sand out, and forms an elastic joint that saves the fastenings; these are consequently found to be always tight, and the wear of the surfaces in contact is insignificant. A pad of tarred felt is accordingly recommended in preference to an iron or steel wearing plate between sleeper and rail; it diminishes the noise and jarring, and though it will not last for more than 75,000 to 100,000 trains, it can then readily be replaced. Meanwhile some other elastic and firm material may yet be found, that will still better withstand wear and rotting, without costing more.

Cracks in the tops of metal sleepers have been started from the corners of rectangular bolt-holes by the operation of punching, and have spread under the action of passing trains; on one of the French lines it was even found that there were more cracks in unused new sleepers in the stores than in those already laid. Though not alarming, these cracks have in some places been guarded against by protecting the sleepers with iron or steel plates or even oak slabs; in other instances the cracks have been traced to their extremities, and prevented from extending further by drilling a small round hole where they terminate; all such sleepers have been allowed to remain in their places without inconvenience. The mild steel made in recent years, particularly by the basic process, stands punching better than the hard and brittle material of ten years ago, which was not nearly so homogeneous. Nevertheless, if punching is still adhered to, the corners of the holes should be kept as round as possible, and the operation should be carefully performed, with a punch that is none the worse for wear. The big cast-iron chairs used for double-headed rails, and also for flange rails, are even better than pads for preventing cracks in the sleeper top. But best of all is to have the bolt-holes drilled; and the longitudinal ribs on the underside of the sleeper, which prevent the square bolt-heads from turning, allow of round bolt-holes being substituted for rectangular. The four holes in each sleeper can all be drilled

simultaneously at a single operation, and at a cost of only three-farthings to a penny per sleeper above the cost of punching them. A sample of every lot of sleepers delivered should be tested cold by doubling it up transversely in the neighbourhood of the drilled holes, till its top surface is turned over inwards upon itself; and by then flattening it out cold under the steam hammer, and again doubling it sharp across at one of the holes through 180° with no rounding inside the bend; this test it should stand without cracking. Ten years ago punching was abandoned for the steel sleepers of the Post pattern on the Netherlands State Railways; and the drilled sleepers have fully answered the expectations formed of them.

Maintenance of the permanent way with steel sleepers was dealt with in Mr. Renson's report for each of the trial lengths of line. Each embodied improvements upon those laid previously; and while the cost of maintenance with the first five of the eleven patterns of sleepers and fastenings was greater than that of the length laid with oak sleepers, with the sixth pattern it became rather less, and with Mr. Post's subsequent improvements much less. Any difficulty of straightening both of the two rails forming the single line of way, in consequence of inaccuracies in the drilling of the bolt holes in the steel sleepers, is got over by the simple expedient of slipping over each bolt a square washer, in which the bolt hole is slightly out of centre, so that each of the four edges of the washer is at a different distance from the hole. The washer bears by one edge against the edge of the rail flange; and thus affords the means of adjusting the rail laterally within the limits of any error in the bolt holes, and so of keeping both of the rails straight and the gauge true. The experience on the Netherlands Railways has shown that no inconvenience arises from the bolts being put in upwards from below; nor are they liable to break through the thread in tightening up the nuts, when made of good material, such as Martin steel having a tensile strength of 28 tons per square inch, with 48 per cent. contraction of area and 23 per cent. elongation in a test length of 8 inches. Oak sleepers are considered preferable to metal under any of the four following conditions: where the road is badly drained; where an embankment has not yet settled down sufficiently; where the subsoil is marshy; or where the ballast is not porous enough. It is better too, in respect of maintenance, that any length of line liable to subsidence from any cause should be laid with wood sleepers, rather than with metal. The annual cost of maintenance of way per mile has been given as about £29 with wood sleepers, and about £20 with metal sleepers properly employed, or 30 per cent. saving. This is confirmed by experience from 1887 on some of the French lines, where the saving in favour of the steel sleepers has varied from 12 to 41 per cent.; the average of six places gives the annual cost of maintenance per mile as about £23 with wood sleepers, and about £17 with steel, or 27 per cent. saving. Owing to their greater

durability, steel sleepers facilitate the realization of a simultaneous renewal for all the constituent portions of the permanent way. With so good a road as the steel sleepers afford, the current work of maintenance can be performed by a single man to each length of line, instead of requiring a gang of platelayers going from place to place.

In France there are already some 350,000 steel sleepers in use, and 150,000 more were ordered in 1898. The Soudan Railway ordered 96,000 in 1899, weighing 67¾ lbs. each. On the St. Gothard Railway wood sleepers are used in the long tunnels; and over the whole line the proportion of steel sleepers is 65 per cent., and of wood sleepers 35 per cent. Other Swiss railways have followed the example of the St. Gothard. Altogether about 1½ million sleepers of the Post pattern are now in use, mostly in Holland, Belgium, Germany, France, and the Transvaal, on the Argentine railways of 5 feet 6 inches gauge, and in Sumatra on ordinary and rack railways of 3 feet 6 inches gauge. For the normal 4 feet 8½ inches gauge the weight of different makes of the steel sleepers ranges from 144 to 203 lbs.; for the metre gauge, from 82 to 94 lbs.; and for the 2 feet 6 inches gauge, from 55 to 68 lbs. On the Prussian State Railways steel sleepers are now in use to the extent of about half the weight of the rails; and the Bavarian State Railways have ordered 24,000 tons of steel sleepers. Two railways in Holland, which have adhered to wood sleepers, have done so in view of being taken over by their government; and for the same reason certain lines in Switzerland and France, already laid with metal sleepers, have done their relaying with wood sleepers, which have been paid for by the sale of the worn out metal sleepers taken out. Apart from Canada and the United States, where timber is so plentiful, the lines laid entirely on metal sleepers are nearly 20 per cent. of the length of the railways in the rest of the world.

A. B.

Influence of the Speed of Trains on the Strength of Rail Joints.

BLUM.

(Centralblatt der Bauverwaltung, 1899, p. 373.)

The Author considers the effect of a wheel rolling over a joint at different speeds, and comes to the conclusion that on the whole the rail joint is less severely stressed at high than at low velocities.

He leaves out of consideration engines not specially built for fast traffic and wheels worn out of truth by brake action; then, with this limitation, considers in great detail the following possible circumstances of a rail joint:—(1) Rail ends at the same height and absolutely rigid; (2) running-off rail rigid and running-on rail yielding to the wheel; (3) high running-on rail;

(4) running-off rail yielding and springing back against the wheel. This may occur at low velocities, and is very prejudicial to the joint. (5) Rails with sunk joints and hogbacked rails. The joints of such rails usually have the running-off rail high, and this causes the strain to diminish with increasing speed.

In support of his conclusions the Author cites the British railways, and contends that the smooth running experienced on them is due in great measure to the high speeds allowed and to the fact that stations, junctions, and points and crossings generally are traversed without slacking speed; the permanent way is of course heavier than the continental track, and the Author admits the necessity of fairly heavy construction and strict inspection for his general statement to hold good.

Finally, the opinion is expressed that if a line is fit to withstand the traffic of frequent goods and slow passenger trains without excessive expenditure on maintenance, it is perfectly able to take fast passenger expresses, with specially built locomotives and first-class stock, with safety to the train and no additional outlay on maintenance.

W. B.

Counter Stresses in Railway Bridges. HENRY S. PRITCHARD.

(Engineering News, New York, 9 November 1899, p. 303.)

The total stress in any member of a bridge is made up of the dead load and the live load. It is well known that in some of the panels of a bridge, a reversal of the shearing stress is set up owing to the presence of the live load, the resultant under such circumstances being called the counter-stress. If L be the live load, and D the dead load, upon any member of which A is the sectional area, then the counter-stress $= \frac{L - D}{A}$; whilst the other stresses, in which no reversal took place, $= \frac{L + D}{A}$. If the live load be suddenly doubled in each case, the dead load being constant, the counter-stresses would be more than doubled, whilst the other stresses are less than doubled; in other words, $2L - D$ is greater than $2(L - D)$, whilst $2L + D$ is less than $2(L + D)$. Thus if a bridge be designed to bear its own weight and a given live load, and the latter be doubled, there will be a more than proportional increase in the counter-stresses, whilst the other stresses will be less affected. It becomes necessary to take into account a possible rapid increase in the concentrated weight of rolling-stock. The Author in allowing for this adds 125 per cent. to the present nominal live load stresses, and after adding to this the dead load stress, allows double the specified maximum working stress, in finding the necessary sectional area. A. P. H.

Vibration of Locomotives and Permissible Speeds.

VON BORRIES.

(Organ für die Fortschritte des Eisenbahnwesens, 1899, p. 115.)

The salient part of this Paper consists of a detailed analysis of the disturbances to the running of a locomotive arising from the effects of the unbalanced moving masses.

These disturbances are due to: (*a*) pressure of the crosshead on the slide bars, producing rolling of the engine; (*b*) effect of the unbalanced portion of the reciprocating masses causing the engine to pull irregularly on the draw-bar and also introducing a tendency of the locomotive to turn on its vertical axis; (*c*) the excess of the centrifugal force of the balance weights over that of the revolving masses of the mechanism.

The Author shows how to determine the nature and extent of the vibratory motion due to each of these causes, and gives illustrative examples from practice.

The vibration most prejudicial to the stability and smooth running of a locomotive, however, does not arise from the action of the revolving or reciprocating masses, but from the inability of the locomotive, considered as one huge mass, to run dead true on a straight road or on a symmetrical curve. The wheels on one side, particularly the leading wheels, over-run those on the other side, and the flanges impinge against the rail, rebounding again and tending to continue and accentuate the motion. The ideal straight course of the engine along the track thus becomes converted into an irregular sinuous progress, which is accompanied by severe straining of the permanent way, such as tendency to loosening of the rail fastenings and widening of the gauge, it also facilitates the mounting of the rail by the leading wheel.

This irregular motion is favoured by a short wheel base, great moment of inertia of the engine round a vertical axis, and a slackness of the gauge.

From a study of certain locomotives which did not exhibit this dangerous oscillation, the Author deduces the following formula, which he recommends to be adhered to in new designs—

$$\frac{\text{Wheel base}}{\text{Length of boiler}} = \left(0\cdot 2 + \frac{2}{300}\,V\right).$$

V is the speed in kilometres per hour. (If V is in miles per hour, 2 becomes 3·2.)

The whole of the Paper is summed up in the form of regulations for the construction and running of locomotives; these deal with wheel base, diameter of driving wheel, balance weights and speeds, and are proposed as amendments of, and supplements to, existing Government regulations.

W. B.

The Bridge across the Seine on the Champ-de-Mars Railway.

ED. WIDMER.

(La Nature, 16 December, 1899, p. 36.)

The new line from Courcelles to the Champ-de-Mars, after traversing the Passy Quarter in a tunnel, is carried across both arms of the Seine by means of iron bridges. The viaduct on the Grenelle arm of the river is in three spans, each of which changes in direction in plan at an angle of 4° 30′ to the preceding one; the railway line being laid on a curve of 169·5 yards in radius. This portion of the work is now complete, but on the Passy arm of the river, on which the chief part of the traffic occurs, there will be but one span, having an opening of 278·87 feet in the clear. The two steel, arched, outer girders will have a rise of one-eighth of their span, and the roadway will be carried at a level intermediate between the springing and the top of the arch. The abutments on which the girders will rest are finished, and good progress has been made with the scaffolding needed for the erection of the iron superstructure of the bridge. On the two shore-ends, this consists of massive timber piling strutted together, but leaving an opening in the centre of the river, 82 feet in the clear, for the passage of boats. It was necessary to complete the roadway across this span, and the work was accomplished on the 9th October last, in the following way. Two steel segmental girders of the necessary length, strongly braced together, and forming a complete metal truss, weighing 45 tons, were put together on an elevated scaffolding, resting on two barges, moored the requisite distance apart by the river bank. The two barges were then towed into the exact position where the trusses were to be fixed, in the centre of the river, and ballasted with a small quantity of water, which sufficed to sink the ironwork on to the temporary abutments prepared for it, and the barges were then towed away from beneath. The entire operation of fixing the span occupied only 2½ hours, during which the river traffic was temporarily diverted to the Grenelle branch of the Seine. The article is illustrated with photographs of the various operations.

G. R. R.

The Water-Power Tube at the Simplon Tunnel.

S. DE MOLLINS.

(Bulletin de la Société Vaudoise des Ingénieurs et des Architectes, 1899, p. 171. 1 plate.)

This is a descriptive article accompanied by a plate of details, showing the construction of the large tube which conducts water from the Rhone to supply the turbines which develop 2,000 HP. for the excavation and ventilation of the Simplon Tunnel.

The tube is 3,270 yards long, with a fall of 1·2 per 1,000, and the velocity of the water in the tube is 6·56 foot per second with a discharge of 282 cubic feet per second. The internal cross section is 6·25 feet by 6·25 feet, and the tube takes the place of an earlier wooden tube, having the same cross section and costing £3 8*s*. per yard, while the new tube cost £4 per yard. This tube forms a girder and it is built on the Hennebique system of concrete, in which are imbedded iron tie-rods and stirrups which take all the tensile stress. It is formed of 596 pieces of 16·4 feet span, and two pieces of 32·8 feet span, the joints being formed upon the supporting piers.

These joints are specially formed and filled with cement, and it is expected that they will allow sufficiently for expansion and contraction of the structure. The contractors have guaranteed that the leakage shall not exceed $1\frac{3}{4}$ pints per minute per yard of the tube, and the Author believes that any leakage which may show itself at first will be stopped by the deposit of the fine mud carried in suspension. The Author points out the many advantages of this method of construction over the use of wood, one being the possibility of strengthening it laterally with heavy stone-work to prevent damage by avalanches and falling rocks.

E. R. D.

The Paris Omnibus Company and Electrical Traction.

(Revue générale des Chemins de fer, 1899, p. 3.)

The Paris Omnibus Company is at present substituting electrical for horse traction on two of its lines where the omnibuses start every five minutes, namely, the Louvre-Vincennes and the Cours de Vincennes-Louvre. The works consist of a central generating station at Montreuil, two terminal charging stations and two large carriage depôts.

The boiler-house contains ten semitubular boilers with a heating surface of 1,800 square metres (19,376 feet). The power is generated by five electric motors of 400 kilowatts each at a tension of from 540 volts to 580 volts. Three of these are driven by a 700-HP. horizontal steam engine and two of them by a 300-HP. Laval steam turbine, making 740 revolutions per minute. The charging stations consist of a central column in the centre of the street containing the apparatus necessary for supplying and measuring the current; in connection with it are terminals enclosed in a sort of fire-plug casing to which a flexible cable can be attached to connect them with the accumulator batteries on the automotors. The conductors are all underground. The rolling stock consists of eighty-five automotors with fifty-two seats in each; they are fitted with a Soulerin air-brake, an electric- and hand-brake and sand-boxes at each end; their weight is from 4,600 kilograms (4·5 tons) to 4,700 kilograms (4·6 tons) each.

To the Paper is appended a copy of the specification.

W. A. B.

The Laon Electrical Railway. BOURQUELOT.

(Revue Générale des Chemins de Fer, 1899, p. 227.)

The town of Laon is built on an isolated eminence 328 feet above the surrounding country; here the population amounts to 9,300, while the suburbs around the base contain 14,625 inhabitants. The railway station is 273 yards from the foot of the flight of steps which lead straight up to the summit, and is the junction of six lines of railway; the passenger traffic is 800,000 per annum. The total length of the electrical railway is 1,617 yards, including 824 yards with a central rack-rail, the minimum radius of curve on the section is 131½ yards, elsewhere 54·68 yards.

The principal works of construction are a viaduct with 2 semi-circular arches of 6 and 7 metres radius, two of 8 metres, an elliptical arch of 18 metres radius and another 7-metre semi-circular arch; a tunnel 49 yards in length, and a double retaining wall for a distance of 175 yards, varying from 13 feet to 20 feet in height. The gauge is 1 metre; the rails Vignoles, of cast steel, weighing 56 lbs. to the yard; the sleepers are oak, 6 feet long by 7 inches by 5½ inches, and 3 feet from centre to centre. The rack-rail is of the Abt type. Electrical power is supplied to the railway station works, and generated by a dynamo driven by two 230 HP. vertical engines. The cars provide 1st and 2nd class accommodation for 40 passengers. The frame is mounted on 2 axles 11 feet apart, with spur wheel in the centre. There are two electric motors of 45 HP. The daily traffic averages 700 passengers; the journey occupies seven minutes, including stoppage at Vaux, the largest suburb. The prime cost, including transformers, is put down at 445,000 francs (£13,690), and promises a profitable return.

The illustrations accompanying the Paper comprise a plan and section, details of the underframing of the tramcars, and photographs of the most important structures.

W. A. B.

Road Bridge over the Southern Elbe at Harburg.

MARTEN and SIEGMUND MÜLLER.

(Centralblatt der Bauverwaltung, 1899, p. 477.)

The new bridge carries the road between Harburg and Hamburg over the Southern Elbe, and has a total length of about 600 metres (1,968 feet). The river proper is crossed in four spans, having each a clear opening of 100·96 metres, besides which there are six approach spans each 31·15 metres in length. The bridge carries a roadway 7 metres wide and two 2·45-metre footpaths.

The abutments and piers are founded on piles driven about 6 metres into sand and gravel. Upon the piles rest concrete bases deposited between sheet-piling and protected against scour by dry stone slopes; these bases rise to low-water level, and upon them are built the actual piers or abutments in brick and stone.

Overhead steel arches span the main openings, the horizontal thrust being taken up by ties under the roadway. The footpaths are carried by the cross girders extended as cantilevers and complete systems of wind bracing are provided in the planes of the upper flanges of the arches and under the roadway.

The approach spans are each supported by two girders underneath the roadway.

The bridge took about $2\frac{1}{2}$ years to build and cost 1,800,000 marks.

W. B.

River Hydraulics. J. A. Seddon, M. Am. Soc. C.E.

(Proceedings of the American Society of Civil Engineers, October, 1899, p. 619.)

The Author draws certain general inferences from a study of the data collected on the River Mississippi. He concludes that the difficulty of studying the regimen of such a river by a consideration of its bed is practically insuperable, and that surface levels lend themselves better for this purpose. The first thing required is to determine the flow which corresponds with the different surface levels, as measured by a gauge at any place. Between tributaries, whenever a river is not varying its surface marks points of equal "stage" on all the gauges, the low-water reading is everywhere the zero of the "stage" scale, and the top of the flood in the same way marks the high water "stage." The zero of the stage at any place is found to change materially between the sequences of high-flood and low-flood seasons, the former tending to clear out the low-water bed, and the latter to fill it up.

The Author finds that the scales of stage in the same river at different points in general bear to each other a constant ratio, time allowance being made for the same stage of the flood to arrive at the lower station when comparing the scales.

The Author proceeds to prove that $mW = \frac{dQ}{dh}$,

where m is the velocity of travel of the flood,

W is the average width of the reach considered,

Q is the discharge of the river for any height h.

m can be measured by automatic gauges at different stations along the river, and if the curve of discharge for varying heights is known at one section in any reach, W, the average width, can be arrived at. The formula also accounts for peculiarities in the variation of the flood velocity at different points along the river.

A. W. B.

The Canalisation of the Fulda from Cassel to Münden.

VOLKMANN and TWIEHAUS.

(Zeitschrift für Bauwesen, 1899, p. 401.)

The principal reasons for undertaking this work were partly to give greater facilities for the already existing traffic on the Fulda, and partly because Münden, where the Weser regulation ends, is less fitted than Cassel to form the termination of an important waterway, from its want of facilities for the collection, storage and distribution of goods.

The annual traffic was estimated to amount to 98,420 tons up stream and 147,630 tons down stream, with a prospective increase; and, although there were to be seven locks in the 17-mile length of navigation, this was considered by the shipping experts consulted to form no bar either to the easy working of the traffic or to the effective competition of the canal with the railway, and experience of the actual working has confirmed this view.

The canalisation was carried out with a channel having a bottom width of 20 metres (65 feet 6 inches) and a depth of water of 1 metre (3 feet 3 inches); this depth, however, has since been increased to 1·5 metre, and it can be increased still further to 2 metres without alteration of the locks or weirs.

The sum of 3,785,200 marks was sanctioned for the works.

The average cost of a lock (200 feet long, 28 feet 3 inches wide, with an average lift about 8 feet 3 inches), together with the accompanying needle weir, etc., was 284,500 marks, while the channel cost, inclusive of the dredging to the final depth, 16,800 marks per kilometre (£1,344 per mile).

The Paper describes the process of designing the works with great minuteness, and is accompanied by figures in the text and several plates.

W. B.

Deep-Water Pier at Pauillac. C. TALANSIER.

(Le Génie Civil, vol. xxxvi., 1899, p. 1 *et seq.*)

The channel of the River Gironde below Bordeaux being dangerous for the navigation of vessels of large tonnage; the Transatlantic Steamship Company, which trades to this port, determined to build a deep-water pier at Pauillac, which would be available for their own and other vessels, and which could be reached at all states of the tide.

The pier is about half-way between Bordeaux and the mouth of the river, *i.e.*, about 31 miles from the sea; and is conveniently served by the Médoc Railway. It is situated about 164 yards from the left bank of the river and measures 1,180 feet by 78 feet, the mean depth of water on each side at the lowest tide being 31

feet. Five lines of rails run the whole length of the pier, and facilities for unloading and shunting are provided by 18 hydraulic cranes and 14 capstans. The cranes are made for 2 powers of lift, 12 lifting 15 or 24 cwt., and 6 lifting 29 or 58 cwt.

The pier is formed of steel girders, which are carried on cast-iron cylinders resting on stone piers; and very full details are given of the construction, and also of the methods of fixing employed.

The hydraulic-power station is situated on the river bank, and contains 2 sets of compound engines and pumps, 3 multitubular boilers, accumulator house and automatic regulators. A complete fresh-water system for supplying ships and locomotives is worked from the same station, the supply being obtained from an artesian well.

The cost of the undertaking was:—

	£
Pier and approaches	150,000
Mechanical equipment	54,000
Dredging and excavating	36,000
	240,000

The total weight of iron and steel employed was about 4,800 tons.

The Paper is fully illustrated by 4 Plates and 15 photographic reprints in the text.

H. I. J.

Nørresundby Pier. C. E. J. Andersen.

(Ingeniøren, Copenhagen, August 1899, pp. 239–241.)

At Nørresundby (North Sound Town), near Aalborg in the north of Denmark, and on the north shore of the Lim Fiord, the old pier, built more than 20 years ago at the west end of the harbour quay, has been supplemented during 1898–9 by a larger pier projecting eastwards from the eastern end of the quay. Owing to the great depth of soft ground before a solid foundation could be reached, the site was dredged to a depth of 15 feet below ordinary sea-level; and round spruce piles were driven till their heads were down to that depth, and were surmounted by rolled-iron pillars reaching 4 feet above the water-level. By this plan of composite piles the timber is wholly protected from the ravages of the pile-worm; while the iron is better able to withstand the action of water and air, which is particularly destructive at the water-line.

The timber piles are about 50 feet long, 15 inches diameter at top, and 9 inches or 10 inches at bottom, where the end is cut blunt. In the head of each is bored a central 5-inch hole to a depth of 4 feet, into which is inserted the iron pillar of 5 inches

diameter throughout; the top of the pile is crowned with an angle-bar ring and flat cap-plate, upon which bears a shoulder forged on the iron pillar. Below the angle-bar ring is another ring of plain iron, and both of these are driven tight on the pile-head; at the bottom of the hole the pile is hooped with two iron rings, tightened round it by wedges. The pier is 300 feet long by 50 feet wide; it is constructed of five parallel rows of piles, twenty-six in each row. The iron columns were stepped into the heads of the piles by a diver; and are all braced together horizontally at bottom by a network of old railway rails, with straps embracing the columns. Along the top of each row of columns are laid longitudinal iron girders rolled of I section, which are secured to each column by a cast-steel cap bolted on the top of the column and to the bottom flange of the girder; any slight difference in level of the tops of the columns is made up by cement packing. Intermediate cross girders are riveted to the webs of the longitudinal girders at intervals of 3 feet, for carrying the flooring. There are two lines of railway, running the whole length of the pier over the alternate longitudinal rows of piles, connected by a crossing; and the flooring is laid with a fall of 1 in 96 towards each line, to let the rain run off. The main flooring is of American yellow pine, 3 inches thick; the outermost planks and those next the rails are secured to the cross girders by bolts through their flanges. All the rest are fixed by bolts passing through long oblong washers with the bolt-hole near one end; this shorter end projects beneath the girder-flange, while the longer end bears against the underside of the plank. The drilling of a large number of holes in the flanges is thus saved, whilst the laying of the planks is greatly facilitated. The planks are covered with a layer of 1½-inch boards, to take the wear; these are also of American yellow pine, and are expected to last longer than Swedish boards of about the same price. The railway rails are bolted down upon the cross girders, by bolts passing through the foot of the rail and the flange of the girder. Along both sides and ends of the pier run two timber fenders, one along the outside of the flooring girders, and the other at the water-line; while fifty fender-piles 12 inches square are driven along the sides and eastern end, and are left standing 5 feet above the flooring. To guard against drift ice, some additional piles are driven at the south-west or upstream corner of the pier; while the unlikely possibility of such an accumulation of ice as might exert an upward force, tending to lift the iron columns out of their sockets in the timber piles, is provided for by iron eye-bolts with two fangs, which are slipped over the columns down to the shoulder at bottom, and secured to the heads of the timber piles by wood screws through the fangs.

As the whole of the new pier is bodily south as well as east of the wall of the harbour quay, the north side of the pier being parallel with the wall, but not quite in line with it, the connecting roadway, carrying the junction between the railway lines

on the quay and those on the pier, had to be made oblique. As recently as 1895 a timber walling of piles and planking was constructed along the length of the quay, which at the eastern end was subsequently burst by the pressure of the ground behind, some of the piles being thereby broken. For carrying the oblique roadway therefore, four separate rectangular timber coffers open at top were constructed, each about 34 feet long and 14 feet wide, and filled with sand and gravel; three were sunk along the face of the quay from the eastern end westwards, in front of the burst walling, and the fourth was sunk in front of the easternmost of the three. The soft bottom was first dredged to a depth of 10 feet below water-line; and as they gradually sank into it, their sides and ends were built up higher, while they pushed out in front of them the soft ground beneath, and were themselves pushed some feet forwards at the bottom by the pressure of the ground behind them, thus reclining backwards against the quay behind, and forming a mound of soft ground in front of them. When they had nearly stopped sinking, a concrete wall was built along the top of the face of each, and its corners were strengthened by old iron railway rails, bent and buried in the concrete. Each coffer could then sink further, independently of its neighbours; this they did so considerably at first, that the concreting was stopped for a time; subsequently they sank uniformly, and without the concrete cracking. The sinking noted in one of them was, in March 13 inches, April $7\frac{1}{2}$ inches, May $3\frac{1}{2}$ inches, and June $1\frac{3}{4}$ inch: or in each month about half as much as in the preceding. By the end of June they had gone down to a depth of altogether from 22 feet to 25 feet below water-line, and had thus extruded from 12 feet to 15 feet depth of soft ground from under them. The position of the coffers as they sank was secured by two vertical piles 40 feet long, driven beforehand in front of each, with two raking piles in front of these; the heads of each set were anchored back to piles driven 80 feet behind them on the quay. Besides these two sets, four more piles were also driven as deep as possible in front of each coffer. It is contemplated ultimately to fill up with coarse gravel and rubble round the coffers, for protecting them from the pile-worm when the iron sheathing, with which for this purpose they were originally covered, becomes rusted off; this external loading will also exert a counterpressure against the outward pressure of the filling inside the coffers.

Along the south side of the pier the bottom has been dredged to a depth of 17 feet of water, and the same will be done later along the north side. Along the oblique junction roadway there will be 150 feet length for berthing small ships with 10 feet to 12 feet of water. Altogether the new work provides 800 feet length for vessels to lie alongside.

A. B.

Floating Elevator-Dredger at Corunna.

(Revista de Obras Públicas, Madrid, 1899, p. 46. 1 Fig.)

As the greater part of the materials to be dredged in the bay at the Port of Corunna for the formation of quays consists of very compact masses of clay and other materials, which might almost be described as decomposed rocks, it was decided to use a steam-dredger with a chain of buckets, rather than one of the suction type. The tower is of wood and is mounted on two pontoons, 89·9 feet long, 16·4 feet beam, and 7·2 feet deep, separated from each other by a space of 20·6 feet, to permit the entrance of a lighter to carry the spoil to the bank. The bucket part of the dredger is driven by a steam-engine of 30 HP. and in the other portion is an engine of 35 HP., driving a centrifugal pump, from which a delivery tube is led to the raised tank into which the buckets discharge the spoil, and the whole is then discharged down an inclined channel on to the bank. The channel is formed of separate pieces, each 22·9 feet long, held up by steel wire ropes from the head of a gib 78·7 feet long. There are several other smaller engines for the various slewing and raising movements. The output of the machine has been over 2,616 cubic yards per day, and the spoil can be discharged at a distance of 73·2 yards. The Author describes it as having given great satisfaction, although the superstructure is of wood and more easily constructed in Spain than if wholly built of iron.

E. R. D.

Monier Plates applied to the Construction of Quay Walls.

WATTMANN.

(Zeitschrift für Bauwesen, 1899, p. 609.)

A wall built on the system described and illustrated in this Paper may be said to consist of a plane framework of iron, of which rolled beams driven as piles form the main sustaining part, anchored back against the face of the wharf and filled in with sheet-piling up to low-water level, and above that with monier plates or with a half-brick wall in cement mortar having flat strips of iron or steel in the bed joints.

The Author makes a comparison of the cost of building a wall or shore protection with the three materials:—(1) Timber; (2) monier and iron framework; (3) masonry. The masonry wall is assumed to be built on a piled foundation, and to have a thickness at the base equal to two-fifths of the height, the front having a good batter and the back being stepped. The costs of the three types in the order named above are respectively 6·53, 9·14, and 24·35 pounds sterling per lineal yard for a wall having a total

height of 4·5 metres (14 feet 9 inches) and a depth of water 2·5 metres (8 feet 2½ inches).

For a total height of 5·5 metres and a depth of water 1·5 metre, the relative costs are as 1 : 1·25 : 2·45.

A further calculation is made to ascertain the ratios of the sums which, if set aside, would provide for the original construction of the wall and for its maintenance and renewal for all time, when the three materials are used. The masonry wall is supposed never to require renewal.

These sums are in the proportions as 1 : 0·84 : 1·66 for the first wall, and as 1 : 0·75 : 1·1 for the higher one.

W. B.

Lighting of the Kaiser Wilhelm Canal. FÜLSCHER.

(Zeitschrift für Bauwesen, 1899, p. 621.)

The lighting of the canal for the purposes of navigation was a problem of considerable interest, there being no example at hand which could serve as a guide to the number, strength and distribution of the lights required, besides the fact that they were to extend over a length of 98 kilometres (61 miles).

It was decided to make no attempt at lighting the entire water surface, but only to place lamps on the banks so as to enable navigators to determine their position. It was found by experiment that 25-candle-power lamps placed 250 metres (274 yards) apart on the straight were sufficient to effect this object. Electric light was preferred to all others from the points of view of cost of installation, running and maintenance, simplicity and reliability. In the public competition for the work manufacturers were given an entirely free hand in the schemes they tendered. There are two separate stations, one for each half of the canal, and in each of these there are two alternate current generators—one acting as a standby—100 kilowatts each, 2,000 volts, with a frequency of 51 cycles per second at a speed of 85 revolutions per minute. They are regulated by a Tesla motor which automatically inserts resistances in the field-coil circuit of a four-pole shunt-wound exciter. A synchroniser, phase indicator, and resistance coils to convert the total work of the dynamos into heat are provided for use when the load is being shifted from one machine to the other, for testing purposes, etc.

There are four separate circuits, two from each station, one for each side of the canal, the division of current being effected between the generators and two groups of transformers by which the voltage is raised to 7,500. On each circuit there are about 240 25-volt glow lamps connected in series, each of which is provided with a choker consisting of an iron core wound with a coil of wire in parallel with the lamp. This arrangement deprives the lamp

of 9 per cent. of the current, but is so designed that if lamps get broken no alteration is required to be made in the running of the dynamos until the breakages amount to more than one-third the number of lamps in each circuit.

W. B.

Consolidation of Made Ground. HOFFMANN.

(Centralblatt der Bauverwaltung, 1899, p. 485.)

The Author describes a successful consolidation of made ground, having a thickness of about 7 metres, by driving, and subsequently drawing, piles close together and filling up the holes with a poor concrete. The piles were 20 centimetres (8 inches) in diameter and were driven 2 feet 6 inches pitch each way. A chimney 65 metres high on a 15-metre square base has been built on the site so consolidated. Only eight piles, each 26 feet long, were required to consolidate 2,150 square metres (23,140 square feet), and the cost averaged 8¼ marks per square metre (9½*d.* per square foot).

W. B.

Experiments in the Increase of Thermal Efficiency in Steam-Engines. E. JOSSE.

(Glückauf, vol. xxxv., 1899, p. 1021.)

This is a notice of some experiments made by the Author at the new machinery laboratory of the Technical High School at Berlin upon a method proposed by Messrs. Behrend and Zimmermann, for utilizing the heat going to waste in the exhaust of non-condensing steam-engines, or in the injection discharge of those working with condensation, the temperature of the former being about 100°, and of the latter 60° to 70°, according to the vacuum maintained in the condenser. The principle of the process consists in substituting a fluid, boiling at a low temperature, for water in an ordinary condensing engine, and which will, therefore, at the temperature corresponding to the vacuum give off vapour of considerable pressure. This vapour is used to drive a separate engine known as a "cold-steam engine," provided with two surface condensers, from which the discharge when liquefied is returned as circulating condensing fluid to the condenser of the hot or water steam-engine. The experiments, which have extended over more than three months, have been made with a 40-HP. compound engine where steam consumption had previously been well determined; the volatile condensing fluid chosen being liquefied sulphur dioxide, a substance whose properties are well known from its use in refrigerating machines, and which vaporised can be used in engines without requiring any lubrication.

The working limits of temperature in the second engine are a maximum of 70° to 65°, corresponding to a pressure of 0·75 to 0·8 atmospheres in the steam-engine condenser, and a minimum of 10° to 15°, according to the temperature of the condensing water. The pressures of sulphur dioxide vapour for these temperatures are given in the following Table:—

Vacuum per Cent. of Atmosphere.	Pressure Kilogram per Square Centimetre, Absolute.	Upper Temperature Limit.		Lower Temperature Limit.	
		Degrees C.	Pressure SO_2 (Absolute).	Cooling Water. Degrees C.	Pressure SO_2 (Absolute).
94	0·659	55	9·7	10	2·338
80	0·204	60	11·05	15	2·813
75	0·254	65	12·53	20	3·347
68	0·317	70	14·80	25	3·970

The surface condenser of the steam-engine is generally similar in construction to those in ordinary use, the steam being condensed outside, and the sulphur dioxide evaporated inside the circulating pipes. The vapour produced which varies in pressure from 10·05 to 13·8 atmospheres (excess) is worked expansively in the second engine, but cannot be completely condensed in the single condenser owing to the comparative warmth of the condensing water, about 15°, which reduces the exhaust pressure to about 1·8 atmosphere. This passes to a second specially cooled condenser, where it liquefies, and is sent back by a feed tank to the steam-condensing plant. The last operation was only successfully arranged after many plans had been tried, but now works perfectly. The escape of sulphur dioxide vapour from the engine has also been completely prevented.

According to the diagrams given in illustration of an experiment made by the combination when the steam-engine was making 4½ and the cold vapour engine 77 revolutions per minute, the extra work realised by the latter corresponded to 56 per cent. of that developed by the steam-engine, without any extra consumption of coal. As the steam consumption of this engine averages about 8·6 kilograms per indicated HP. per hour, the effect of the combination was to reduce the consumption to 5·5 kilograms per indicated HP. per hour. With non-condensing engines the saving would be proportionally greater, and the Author considers that if the system were to be adopted at large power stations of about 3,000 HP., where central condensing can be adopted, an extra power of 1,500 HP., or, in the case of non-condensing engines, about 2,000 HP., might be got without increasing the consumption of coal.

H. B.

Steam Meters.

(Ingeniøren, Copenhagen, 1899, pp. 211–212 and 230–232.)

Four meters are described. The plan of the first, by A. Friedeberg of Berlin, is to condense and measure continuously a portion of the steam flowing through the main steam-pipe. Inside a horizontal length of the main a flap-plate hung from a horizontal axis actuates through an internal sector and rack a conical plug-valve controlling an opening in the top of the main. When no steam is being used, the plate hangs vertically, and keeps the valve closed; when steam is flowing through the main, it turns the plate more or less towards a horizontal position, thereby opening the valve correspondingly; and the steam escaping through the valve is condensed in a worm. The water from the worm is either collected in a measuring-tank provided with a gauge-glass, or is delivered upon a bucket-wheel, the revolutions of which are indicated upon a counter arranged to show the corresponding quantity of steam flowing along the main.

In the second meter, which is used by the New York Steam Company, the steam flowing along the main steam-pipe is made to pass upwards through a vertical chamber, into which it enters at bottom through an orifice fitted with a conical valve of long taper, and lifts the valve in proportion to the quantity of steam passing through. The height of lift is limited by an adjustable set-screw, and is indicated by an arm, which records it by a pencil on a paper drum driven by clockwork. A piston attached to the bottom of the conical valve works in a cylinder of water, forming a dash-pot to check sudden oscillations of the valve.

The third meter is constructed by J. Lindenheim of Berlin. From the horizontal portion of the main steam-pipe a split of steam is led off through a port, which delivers it tangentially upon a fan-wheel with six radial vanes, mounted on a horizontal spindle in a chamber fixed on the top of the main; the fan is rotated by the passing steam, which is returned into the main through a horizontal nozzle, placed centrally in the main, and delivering in the direction in which the steam flows along the main; the current of steam surrounding the nozzle thus produces an effect of suction, which helps to draw the split of steam through the fan chamber. Outside the fan chamber is an ebonite cone of hyperbolic outline, sliding on a feather upon the fan-spindle, and revolving with the fan. In contact with the cone runs a friction wheel, pressed against it by a spring, and connected with a counter. The steam being also admitted into a series of three shallow cylinders, whose covers are thin corrugated disks, its pressure bulges them centrally, and through a long multiplying lever their cumulative bulging is caused to slide the cone along the fan spindle, and so to bring a larger diameter of the

cone into contact with the friction-wheel, thereby augmenting the record of the counter.

In the fourth meter, by M. Gehre, there is fixed across the main steam-pipe a block, through which the steam passes through a hole of only about one-third the area of the main. From each face of the block a port leads the steam to the opposite sides of a piston held midway in a cylinder by helical springs. Hence the difference between the higher steam-pressure in front of the block and the lower pressure at its back moves the piston to a proportionate extent; and by a multiplying lever its movement is communicated to a slide of curvilinear outline, against which works an arm carrying a pencil, for recording upon a paper drum driven by clockwork the movements of the slide and piston, and the consequent flow of steam through the main.

A. B.

Distribution of Steam Pressure in Tubes.

HERM. FAHLENKAMP.

(Verhandlungen des Vereins zur Beförderung des Gewerbefleisses, 1899, p. 249.)

These experiments were made on a tube inserted into the wall of a steam-engine cylinder. The engine was blocked at the dead points and the steam-pressure was varied by throttling. The relative sizes of the cylinder and the various tubes employed were such that, in the Author's opinion, the velocity of the steam in the cylinder could be neglected. Pressure-gauges were fitted at points along the tube, and were read when the steam was escaping from the full-open end, the pressure in the cylinder being known. Tubes of various lengths and diameters were experimented with.

The Author gives Tables and Diagrams of the results, but refrains from discussing them, as he hopes to obtain more complete material for that purpose by repeating the experiments with larger tubes.

W. B.

The Use of Coal-Dust as Fuel for Steam-Boilers.

(Schweizerische Bauzeitung, 1899, p. 63. Figs.)

The first experiments made in Switzerland on the use of coal-dust as fuel for steam-boilers were carried out in 1896 by the wish of Mr. Gressly at the Berne small arms factory, under the superintendence of the Swiss Society of Boiler Owners. The boiler used was of the Sulzer Cornish form, and the "Mehl" grate, and Wegener system of firing were both tried. The results appeared in the 1896 report of the Society and showed that the dust could

be burnt smokelessly with a thermal efficiency of 20·93 per cent., and a saving in cost of steam of 15·5 per cent. Subsequently at the Gerlafingen ironworks a Lancashire type of boiler was fitted up for coal-dust burning, and since the spring of 1897 Messrs. Sulzer have given the subject great attention. The grinding of the coal to form the dust is the most expensive part of the process. In Basle the Warteck Brewery took up the subject and used the Wegener apparatus, and comparative tests were made with this and the "Cario" system of firing, and proved favourable to the former.

At the Polytechnic at Zurich the Wegener system was used for a time in an old boiler, but was given up, as it was feared the excessive heat produced would injure the furnaces. The Author points out that the boilers require to be specially adapted for dust burning. For successful results the dust must be in the form of very fine powder, and if the coal be damp it is difficult to grind.

A Table is given in the original of the results obtained at the cement works at Ehingen as compared with firing in a Ten-Brink furnace, and the costs of the former appear very favourable, as the dust firing enabled a very cheap kind of coal to be used. It appears, however, that the coal-dust firing has been subsequently given up, not, however, owing to inherent defects in the system, but because the excessive heat produced by the dust was localised so much that it caused damage to the furnaces of the Ten-Brink boilers, which had not been specially designed for the use of dust, but merely temporarily altered for the purpose. The Author considers that the process is well worth attention, with the special kinds of coal which produce a great deal of slack.

E. R. D.

Examination of Asbestos Cloth for Packings. A. Jakobsen.

(Ingeniøren, Copenhagen, July, 1899, p. 204.)

In the chemical laboratory of the Danish State Railways at Copenhagen the Author has had occasion to examine various kinds of asbestos cloth,[1] which might be applicable for packings; and has obtained results in some respects unexpected, which presumably may be of general interest, as he has not met with previous investigations of the same kind. His object was to find a ready means of ascertaining the value of specimens of asbestos, in respect of their tensile resistance to rupture in their original condition, and also when heated for a length of time to about the temperature that packings are exposed to in use. The tests were made in a machine on strips about 7 inches long and $\frac{3}{8}$ inch wide; and the results are tabulated in figures denoting the length of strip which would just rupture itself when hung up by one end. For calculating this length, the total pull put upon the strip in

[1] The Danish designation is asbestos "paste-board."

the machine is divided by the weight of the strip, and the quotient is then multiplied by the constant 0·18 for the length in metres or 0·59 for the length in feet. Each strip has a maximum or a minimum strength, according as it is cut lengthways out of the sheet or across. The limit to the pull of the machine was 44 lbs., at which some of the longitudinal strips were not ruptured; but their thickness is not stated. Out of five lots of asbestos, three showed an important difference between their maximum and their minimum strength; wherever therefore absolute strength is the chief consideration the minimum must be taken, and not, as is apt to be done, the mean between this and the maximum. When the asbestos is heated to a temperature of about 410° Fahr., which is what the packing rings in locomotives are exposed to, its strength in both directions falls materially. In the Author's trials the test strips were kept at this temperature for sixty-four hours before testing, after which period none of them showed any further loss of weight; presumably therefore the water of crystallization in the raw material, and any oil and other admixtures, which are generally evaporated at 410°, had been driven off. Another condition affecting the strength is dampness, as ascertained by keeping some of the test strips for several hours in air saturated with moisture under a bell glass, and others in the ordinary air of a room. After drying them all at 212° Fahr. for about two hours, the strength in both directions was found to be largely increased, if they were then tested immediately on cooling. Hence it is futile to attempt to test asbestos by tearing it by hand in both directions, because its dampness may vitiate any opinion formed therefrom. Neither can the purity of the manufactured sheet be determined from the quantity of mineral asbestos it contains, as calculated from its content of the two principal ingredients, silica and magnesia: for not only does mineral asbestos obtained from different places vary largely in chemical composition, but also some kinds, though having the same composition, may be worthless. The shrinkage of different samples on being heated from 212° up to 410° Fahr., and even above 410° until they glow brightly, shows a great range of variation; it is therefore impracticable to determine by this means the quantity of organic matter they contain, such as dextrin, starch, and oil.

Examination under the microscope is urged. Although in the State Railways tests no idea could thereby be formed as to the quantity or nature of the organic admixtures, nor how far the grains always interspersed between the individual fibres are mineral asbestos or other inorganic substances, yet the fineness and length of the asbestos fibres are rendered plainly visible; and the more finely the individual fibres are separated from one another, and the greater their length, the stronger will the asbestos cloth prove. How far tensile test and microscopic examination confirm each other is illustrated by the remaining two out of the five lots of asbestos experimented upon, which

were both manufactured in the same works, for use not as packings but as non-conducting coverings for boilers, &c.: the specimens tested of one lot are seen under the microscope to consist of long fibres without many interspersed grains; the fibres themselves again consist of bundles of finer fibres, which in the process of manufacture have not become separated from one another, and therefore cannot felt so well. This conclusion is confirmed by the lower strength of these same test strips, as compared with the other lot from the same works; and while in both lots the strength is practically the same longitudinally as transversely, that of the worse-felted cloth is not inferior to the minimum strength of many other makes. Hence, while chemical investigation proves here to be of no importance, tensile tests should be accompanied by microscopic examination, whereby valuable information can be obtained for judging the quality of asbestos cloth.

A. B.

The Dopp Petroleum Motor. Dopp.

(Verhandlungen des Vereins zur Beförderung des Gewerbefleisses, 1899, Sitzungsbericht, p. 140.)

The Author states that while the oil engines tested by the German Agricultural Society at Berlin in 1894 consumed from 0·5 to 0·7 kilogram (1·1 to 1·5 lb.) per B.HP. per hour, this increased in practice to 1 kilogram (2·2 lbs.) per B.HP. per hour.

In 1896 the Author exhibited at the Berlin Trades Exhibition four oil engines of 1, 2, 5 and 8 HP. respectively, all of the four-cycle type. A sheet of white paper held immediately in front of the exhaust of any of these engines remained perfectly clean, and the perfect combustion of the oil was also proved by the fact that the common exhaust of the four engines did not, during the five months of the exhibition, discolour the foliage of a tree directly over the top of the exhaust tube. No tests were made by the judges to determine the efficiency of any of the oil engines exhibited, but the Author obtained the services of two independent engineers to test his motors. The result showed that the 2-HP. engine consumed 0·252 kilogram (0·554 lb.), the 5-HP. engine 0·25 kilogram (0·55 lb.) per B.HP. per hour. Subsequently the Prussian Ministry of Public Works submitted to an 11 months' trial a 12-HP. petroleum motor built by the Author. After a run of 2,808 hours the average consumption of oil was 0·197 kilogram (0·423 lb.) per effective HP. per hour.

A test by F. Dopp, jun., carried out on one of the Author's 6-HP. motors, showed an oil consumption of 0·234 kilogram (0·516 lb.) per HP.-hour; running light at the normal speed of 250 revolutions per minute, this same engine required 0·674 kilogram (1·48 lb.) per hour, and when the revolutions were reduced to 200 the consumption of oil fell to 0·397 kilogram

(0·9 lb.) per hour. Referring to the Diesel motor the Author states that the catalogue price of the 20-HP. engine of this make —£600—is double the price of the same power of engine as manufactured by his firm.

Mr. Dopp also avers, and quotes supporting opinions to the effect that the expansion of the burning gases in the Diesel motor is not isothermal, that in fact the temperature rises so considerably after ignition as to necessitate the application of cooling water as in an ordinary gas or oil engine.

W. B.

3,000-*HP. Dynamo at Berlin.*

(Zeitschrift des Vereines deutscher Ingenieure, 1899, p. 1349.)

There are two of these dynamos working, while a third is under construction in the workshops of Sulzer Brothers. They are driven by vertical triple-expansion steam-engines. The cylinders are mounted one above the other. The diameter of the high-pressure cylinder is 865 millimetres (34 inches), that of the mean 1,250 millimetres (50 inches), while the low-pressure cylinder measures 1,550 millimetres (61 inches).

At 85 revolutions, 1,350 millimetres (54 inches) stroke, and pressure of 12 atmospheres, the horse-power developed is as follows:—1,740, 2,270, 2,800, 3,330, 3,860, with 11, 18, 25, 35 and 50 per cent. of the full head of steam in the high-pressure cylinder.

The high-pressure cylinder is mounted above one of the low-pressure cylinders, and the mean-pressure cylinder above the other, one piston working each pair.

The bed-plate is in two sections, each having two main-bearings, the double-crank axle is also in two sections with flange connections; at each end it carries a massive fly-wheel and a direct-current dynamo. The framework of the engines and cylinders is rigidly connected with the bed-plate by massive columns and bolted to the girders overhead.

The steam-ports are in the top and bottom cylinder covers, the valves are vertically suspended, except in the high-pressure cylinder, which is provided with Sulzer valve-gearing. Only one regulator shaft is employed; the length of the valve-rods is thus considerable; they are hollow tubes and move in a true vertical line. The lubrication is automatic; a well in the bed-plate receives the waste, which is pumped up into tanks, purified and used again. Porter regulating-gear is employed; the novel feature about it is that the regulator handle, which consists of a long lever, has at its extremity a small tank attached, a flexible hose supplies the water, the quantity of which is regulated by the engine-driver, and the speed is thus altered in the smoothest manner possible. The driver's platform is at a level two-thirds the height of the engine; the switch-board is on the same level.

To counteract to some extent the vibration of this ponderous machinery the cranks of the main shaft are set at an angle slightly less than 180°.

The boilers are on a floor above the engines. Each dynamo affords a normal supply of 1,000 kilowatts at a tension of from 250 volts to 280 volts and 85 revolutions; when working the tram-lines they are coupled in pairs, when supplying the electrical light works the connections are in parallel.

W. A. B.

The Machinery of the Austrian Coast Defence Ships, "Monach," "Wien" and "Budapest."

(Mittheilungen aus dem Gebiete des Seewesens, 1899, p. 420.)

The machinery of the Austrian coast defence ships, "Monach," "Wien" and "Budapest," is identical, except that the two first-named have cylindrical boilers, while the "Budapest" is fitted with Belleville boilers. Each vessel has two sets of triple-expansion engines, with three cranks making angles of 120° with each other and together capable of developing 9,900 I.HP. There is no rigid connection between the cylinders, which are only held together at the top by two round bars passing through cast lugs. It is claimed for this arrangement that it cheapens the cost of the engines, saves weight, reduces vibration, and simplifies the design. The relation of the capacities of the three cylinders to one another is 1 : 2·75 : 5·54; with the maximum of 140 revolutions per minute the average piston speed is 14 feet per second.

The high-pressure cylinder steam-jackets receive steam at the same pressure as the cylinder, but the boiler steam admitted on occasion to the intermediate and low-pressure cylinders is reduced by throttling to 93½ lbs. and 38½ lbs. per square inch respectively. Piston valves are fitted to the high-pressure cylinder, balance slide valves to the other cylinders; all the cylinders have cast-iron piston rings fitted with spiral springs exerting a pressure of 2·34 lbs. per square inch of surface.

The propeller and thrust shafts are hollow and about 13 inches in diameter; the crank shaft is solid. The pressure on the thrust blocks when the engines are working at full power is about 71 lbs. per square inch. The manganese bronze twin screws have a diameter of 4,420 millimetres (14·4 feet) and projections of 14·5 per cent. of a circle of that diameter.

At full power the condensers have an area of 1½ foot per I.HP.

The cylindrical boilers, of which there are three double- and two single-ended to each ship, work at 11 atmospheres (162 lbs. per square inch) pressure. The total fire-grate area in each set is 53·11 square metres (572 square feet), the total heating surface 1,468·29 square metres (15,800 square feet). The boilers developed

9,900 I.HP. with a pressure of 35 millimetres (1·37 inch) of water in the stoke-holes.

The "Budapest" has sixteen Belleville boilers in two compartments working at 250 lbs. per square inch, reduced before passing to the engines to 11 atmospheres. The total grate area equals 66·8 square metres and the heating surface 1,982·4 square metres. The maximum power developed reached 9,300 I.HP., attained without unduly pressing the boilers.

The description is illustrated by three plates in the text and a photograph of the "Wien."

W. B.

150-*Ton Revolving Crane at Bremerhaven.*

(Zeitschrift des Vereines deutscher Ingenieure, 1899, p. 1481.)

This crane is one of the largest in the world, and is erected at the Imperial Repairing Dock for fitting boilers and machinery to the liners and ships of the Imperial Navy. The main support consists of a rectangular structure formed by four wrought-iron verticals rigidly braced together; its height is 86 feet, tapering towards the top. The feet rest on shoes tied by seven long bolts to anchors sunk in the solid masonry foundation. At the top there is a circular well or ring constructed of wrought-iron which serves as a guide to the horizontal wheels of the central revolving shaft; this shaft is of the same construction as the above, but tapers downwards and rests on a single horizontal axle or pivot, which is supported on a revolving platform worked by electrical power. The shaft carries a lattice girder 160 feet in length, with a traveller with hoisting gear and a counterweight, its total height from ground level is 118 feet, the distance from the face of the quay-wall to centre of chain being 44 feet.

The total weight of shaft fully loaded is 521 tons. A direct-current motor of 26 HP. turns the crane, which occupies 7·2 minutes. The hoisting tackle is likewise worked by electrical power, and consists of a steel-wire rope 2·36 inches in diameter rove in two, three and four sheaved massive blocks.

The material used in the construction weighs 368·5 tons, rather less than half the weight of the American crane of the same capacity.

The Author gives full details of the construction and operation, and supplies numerous illustrations of the machine.

W. A. B.

New Forms of Sprengel Pump. G. GUGLIELMO.

(Il Nuovo Cimento, 1899, p. 120.)

The forms of mercury pump described in this Paper are suitable for exhausting Rontgen ray tubes, and are more simple and easy to make than the ordinary Sprengel. An elongated bulb or chamber is attached to the top of the fall tube, serving as a cup to ensure the regular distribution of the mercury in the form of drops. A side tube attached to this chamber bends downwards and dips into a vessel of mercury, which it siphons over into the pump, the action being started by suction from the bottom of the fall tube either with a pump or by the mouth. The end of the siphon tube is bent up, and receives the point of a needle, which serves to check or stop the flow when necessary. A slight modification enables this valve to act automatically, closing the orifice when the supply of mercury runs short.

The Author describes some forms of Rontgen ray tubes in which the electrodes are sealed in with cement, and describes some cements suitable for the purpose.

Resin melted with a little oil does not stand a vacuum well, but resin with paraffin or with rubber is free from this objection. A rather high temperature is required to effect the mixture, but when made it is very fluid, and does not give off bubbles under the action of the pump.

G. J. B.

The Mammoth Pump. E. S.

(Ingeniøren, Copenhagen, July, 1899, p. 196.)

Although various useful contrivances have been devised for raising liquids by direct air-pressure, their application has been restricted to a few operations, owing partly to the special arrangements required, and partly to the poor economy resulting; their working moreover is intermittent. Yet a plan was devised more than a century ago, which is free from these drawbacks, and which has latterly given such good results that it has already been extensively applied for many purposes. In 1797 Carl Emanuel Löscher, superintendent of mines, described the invention of an "aerostatic apparatus, whereby, without any bucket or pump-work whatever, water can be raised from a well to a height of some hundred yards." The principle consisted in sinking a tube in the water with part of its length standing above the surface, and then forcing air through a smaller tube into the submerged orifice of the larger; the air bubbles mixing with the water in the larger tube so reduced its specific gravity, that by the pressure of the external water column the mixture of water

and air inside the tube was driven up above the water level, and flowed out of the top of the tube. Löscher's experiments led to no practical application of the plan at the time; and the idea lay dormant till 1846, when it was taken up by Cockford, who on this principle raised petroleum out of bore-holes in Pennsylvania. The method was further improved by Frizzel in Boston, Alexander Schnee, Dr. Pohlé in America, and the Pneumatic Engineering Company in New York. In France sulphuric acid was first raised by Gondry in 1886 on this plan; the apparatus became known under the name of "emulsor," and was taken up with advantage by the Compressed Air Company, and applied to raising water. After the Chicago Exhibition of 1893 it received a more general application in Germany through the firm of A. Borsig in Berlin, by whom more than 130 "mammoth" pumps, as they call them, have already been erected. In the autumn of 1898 a number of experiments on different constructions of these pumps were carried out by Professor Josse in the mechanical laboratory of the Technical High School, Berlin, and in certain manufactories.

In the Berlin laboratory one of the mammoth pumps was placed in a tube well of 6⅛ inches diameter and 98 feet depth, in which the water stands 13 feet below the surface of the ground. The pump consists of a plain tube 3 inches diameter, forming the rising main, at the bottom of which is a foot-box; and of an air tube 1½ inch diameter, through which compressed air is led down into the foot-box. The two tubes run close alongside each other down the well, and are fixed air-tight in the closed top of the foot-box, which has an inlet opening in the bottom for the entrance of the water from the well. The orifice of the air-tube is at the very top of the box, and that of the rising main is 3½ inches lower, and the air can flow into the rising main all round the circumference of its orifice; the bottom inlet orifice from the well is 7 inches below the top of the box, so that the air forced down into the box escapes up the rising main, in preference to blowing out through the bottom into the well. Above ground a short length of the rising main is made of glass, for observing the ascending mixture of water and air. From the top of the rising main the water flows out freely into a tank, where the air becomes separated from it. The driving power for propelling the mixture of water and air up the rising main is the head of water in the well above the bottom of the rising main. Hence the depth of submersion of the pump must be regulated according to the height to which the water is to be lifted; as a rule it is from one to one and a half times the height of lift. The pump starts working as soon as ever compressed air is admitted to it in sufficient quantity and at suitable pressure; it can thus be started from a distance by simply opening the air-cock, without the need of erecting an engine-house at the well.

For a yarn spinning mill at Zwickau, near Chemnitz, Saxony, 880 gallons of water per minute are raised 43½ feet into an open tank over a tube well, and flow thence into a service reservoir

situated at $13\frac{1}{2}$ feet lower level in the mill at a distance of more than half a mile. The compressed air is supplied from a steam compressor in the mill at 2 atmospheres pressure. This is the largest pump hitherto erected; the rising main is $7\frac{1}{2}$ inches diameter, and the air tube 5 inches; the depth of submersion is 63 feet, or half as much again as the height of lift; the air supply at atmospheric pressure is $2\frac{3}{4}$ times the volume of water raised; and the efficiency, or ratio of work done in water lifted to work done in air compressor, is 28·8 per cent.

For a sugar factory in Glogau, near Breslau, Silesia, at a distance of more than a quarter of a mile from a branch of the Oder, and at about 50 feet higher level, the water is raised 62 feet at the river side, and led to a service reservoir at the factory through an open sloping launder to get rid of the air. There are two mammoth pumps, each capable of raising 660 gallons per minute with compressed air of 3 to $3\frac{1}{2}$ atmospheres pressure; each pump has its own air-tube, for convenience of working either pump separately or both together, according to the supply required. The depth of submersion is 95 feet, or half as much again as the height of lift; the air supply at atmospheric pressure is from $2\frac{7}{8}$ to 4 times the volume of water raised; and the efficiency, or work in water lifted as compared with air-compressing work, is from 24·3 to 14·8 per cent.

For pumping hot liquids, where ordinary pumps cannot lift by suction, the mammoth pump is under no disadvantage of this kind; on the contrary its efficiency is increased, owing to the volume of the air being augmented by the heat of the liquid. At a sugar factory in Stendal, near Magdeburg, Saxony, hot water at 195° to 200° Fahr. is raised 14 feet, with a depth of submersion of 21 feet.

For raising water from great depths, where ordinary pumps would require a large well to be sunk deep enough for keeping their suction lift within the atmospheric limit, and roomy enough for containing bulky slow-revolution pumps with long rods and for allowing access thereto, the mammoth pump requires simply a tube well just large enough to hang it in. It is devoid of clacks, flap-valves, and all other moving parts, with their inevitable wear and tear; and as the bore of the rising main is free throughout its entire height, stoppages are unlikely to occur, and uninterrupted continuity of working may be relied upon. For the same reason mud can be lifted by the mammoth pump, which has already been employed for dredging in Holland with good results.

For lifting brine, its simplicity is a great advantage; when too far corroded by the salt water, the rising main and air tube can be renewed without serious loss of time or heavy expense. At the Deutsche Solvay Werke in Saaralben, Lorraine, there are ten mammoth pumps, each raising per minute 48 gallons of brine of 1·2 specific gravity to a height of about 60 feet, out of bore-holes 840 feet deep and 12 inches diameter. Above the brine at the bottom there is fresh water, in which the pumps are submerged

to a depth of 400 feet, leaving 380 feet depth below the foot-box of the pump, into which the brine is led up by a pipe carried down to this further depth. Hence the head of fresh water in the bore-hole has to lift up to the foot-box of the pump a column of unmixed brine of this height and of one-fifth greater specific gravity, in addition to the column of mixed brine and air above the foot-box. Although the actual height to which the brine has to be lifted above the water surface in the bore-hole is only about 60 feet, the calculated height of lift for fresh water is 230 feet with the same pump; and in experiments with this greater height, and with an air pressure of 12 atmospheres, the air supply at atmospheric pressure was $5\frac{1}{8}$ times the volume of water raised, and the efficiency was 20 per cent.

For the water supply to the town of Oppeln, near Breslau, Silesia, a horizontal compound engine drives from its high-pressure piston-rod a double-acting high-pressure pump; and from its low-pressure piston-rod an air-compressor, which supplies compressed air for working five mammoth pumps, placed in wells at distances of from 25 to 300 yards from the engine-house. Each pump raises 150 gallons per minute through a height of 90 feet, from 70 feet below the engine-house floor to 20 feet above, whence the water flows to the high-pressure pump in the engine-house, by which it is pumped up into a high-level reservoir. The proper distribution of compressed air to the several mammoth pumps is automatically controlled by floats in the wells, actuating valves in the branch air-pipes. The whole arrangement came into operation in August 1898, and has so far worked satisfactorily.

In the experiments at the Berlin laboratory the Borsig mammoth pump with plain tube for rising main was compared with a "corrugated-tube pump" by another maker, in which the rising main, while of circular section throughout, was corrugated transversely, under the notion that in the ascending mixture of water and air the water would thereby be prevented from slipping backwards relatively to the air bubbles, and that the delivery would consequently be increased. Two of the plain rising mains were accordingly tried, of $2\frac{3}{4}$ and 3 inches bore, corresponding with the smallest and largest diameters of the bore in the corrugated tube; each of the three rising mains was 120 feet high from inlet at bottom to outlet at top. The pipe supplying the compressed air to the well was 50 feet long, and contained many right-angle bends. The experiments, which are tabulated in full detail, showed that, so far from the delivery being increased with the corrugated tube, it was less than with the plain rising main; whereas with the latter the highest efficiency, or ratio of work done in water lifted to work done in air-compressing, was 45 per cent., the efficiency with the corrugated rising main under otherwise similar conditions was only about 25 per cent., little more than half as much water being raised. The corrugated rising main however had no foot-box, but the air pipe was simply curved upwards at bottom and inserted centrally into the orifice

of the rising main. The Borsig pump was accordingly tried in the same way, without a foot-box; but was then found to deliver 20 per cent. less water than with its foot-box, for the reason probably that with the foot-box the air enters the rising main all round the circumference of its orifice, and thereby mixes more thoroughly with the water than when supplied in a single central jet.

From the experiments generally, both in works and in laboratory, it is concluded that the limits of variation are wide for the quantities of water which the mammoth pumps can deal with. For heights of lift ranging from 15 to 50 feet the required supply of air at atmospheric pressure may be reckoned at from two to three times the volume of water lifted. The most efficient depth of submersion is from one to one and a half times the height of lift. When the height of lift is increased beyond the depth of submersion, the relative consumption of air increases also, and consequently the efficiency diminishes. With increase in air supply, the quantity of water lifted increases up to a certain maximum, beyond which it declines with further increase of air. The smallest consumption of air, measured at atmospheric pressure, was $1\frac{2}{3}$ times the volume of water raised, in an experiment in which the 3-inch pump was lifting 55 gallons per minute; and by varying the air supply the delivery of the same pump can be varied between 10 and 90 gallons per minute, without materially impairing the economy of working; above 100 gallons per minute the air consumption rises too rapidly. In larger pumps the limits of economical delivery are narrower. An increase of 20 per cent. in the area of the bore of the rising main, from $2\frac{3}{4}$ to 3 inches diameter, was attended by an increase of only 1·2 per cent. in yield of water. The velocity of the water in the rising main should not exceed 5 feet per second, according to the experiments, in which it ranged from 5 feet up to 8 feet per second.

At certain of the works using the mammoth pumps the Author estimates that, if pumps driven electrically had been substituted, the efficiency realised would have been about 45 to 50 per cent.; and that, if compressed air had been substituted as the driving power, the efficiency would have been about 30 per cent. But even though the air compressors used with the mammoth pumps were not of first-class construction, the actual efficiency of these pumps in the experiments made at the works has been found to range between 22 and 28 per cent., and rose to about 45 per cent. in the most favourable of the laboratory trials. Moreover, in comparison with pumps driven either by electricity or by compressed air, the mammoth pumps enjoy the advantage of greater simplicity, of being cheaper to erect and maintain, and of requiring no attention whatever, either for starting or during working. Their merits are most conspicuous where the pumping has to be done at a distance from the source of power, with the greatest possible simplicity of construction and certainty of working, and where water has to be raised from great depths.

A. B.

The Kaselowsky Pumping Engine. C. François.

(Revue universelle des Mines, August, 1899, p. 152.)

This system of working pumping engines underground by a circulating column of water, under pressure from steam power at the surface, has been applied to a considerable extent in the deep pits of the Westphalian coal-fields, one of the most notable examples being that at the Gneisenau pit of the Harpen mines near Dortmund, where a long stroke direct-acting pump is worked at 100 atmospheres pressure. This has since been surpassed by a new installation at the Pluto mine at Wanne, where the working hydraulic pressure has been brought up to between 200 atmospheres and 250 atmospheres (3,000 lbs. to 3,750 lbs. per square inch). The plant includes a two-cylinder steam-pressure pumping engine at the surface, two direct-acting hydraulic pumping engines underground, each with its own rising main and an independent circulating system for the power water, giving four lines of pipes in the shaft, an arrangement that has been adopted in preference to discharging the exhaust of the pumping engines into the rising main, to admit of the continued use of the same water with an addition of vaseline, whereby the coefficient of friction in the pipes is notably reduced. Pressure regulators are inserted in the power circuit at the surface and at the bottom of each of the rising mains. These are small vertical plungers under the full pressure of the water, acting against the resistance of enclosed masses of air at about 25 atmospheres pressure in larger cylinders. The driving water, admitted through a central fixed pipe, acts inside the pump plunger, which forces the water out of the pump barrel on the back stroke and at the same time exhausts the spent water and fills the barrel of the opposite pump, the distribution being effected by a two-piston slide valve actuated by a rod and tappets attached to the moving part of the pump; the closing being effected by the engine itself and the admission by the adjoining engine, for which purpose they are arranged as in duplex engines, one being in the middle when the other is at the end of the stroke, an arrangement which does away with the necessity of fly-wheels or other rotating parts. The working speed is only from 15 to 20 double strokes per minute, and the pumps can be stopped and started from the surface.

The loss of pressure owing to the small size of the driving column (2·32 inches) is 26 atmospheres, 210 atmospheres at the surface giving 184 atmospheres underground, or 87·6 per cent. This loss, although considerable, is less than that experienced with steam sent down from the surface. At Gottessegen, where the pipes are better proportioned, as much as 94·5 per cent. is realized.

The useful effect realized is about 69 per cent., which is about the same as that of an underground steam pump under favourable

conditions, but at Gottessegen it is as much as 74·5 per cent. Taking both systems as of equal value, there are certain advantages in favour of the use of high-pressure water, due mainly to the small size of the different parts both fixed and moving, as well as the ability of working when submerged, which is impossible with steam. The principal defect is that it is rather expensive.

The principal dimensions are as follows—

Steam-engine at surface, cylinder diameter . .	870 millimetres.
„ „ „ stroke	1,100 „
„ „ „ number of revolutions	40 per minute.
Pressure pumps, plunger diameter	78 millimetres.
Pressure pipes for power water, diameter . .	60 „
Return „ „ „ „ . .	70 „
Rising main	180 „
Pressure regulator, air piston, diameter . . .	520 „
„ „ water piston „ . . .	160 „
„ „ pressure in air cylinder . .	20 to 22 atmospheres.
Underground motor, injection pipe, diameter .	135 millimetres.
„ „ plunger „ .	235 „
„ „ length of stroke	800 „
„ „ number of double strokes .	18 per minute.
Pressure of driving column	210 atmospheres.

H. B.

The Aspen Mining District, Colorado. J. E. Spurr.

(Monographs of the United States Geological Survey, vol. xxxi.)

This monograph, which covers 250 pages and is accompanied by an atlas of geological maps, contains a detailed account of the structure of the Aspen mining region, in which is situated the Cowenhoven adit level described by D. W. Brunton.[1] Into sedimentary rocks, which in the Aspen district attain great thickness, two distinct sheets of igneous rock were intruded, probably in Cretaceous time. Subsequently to these intrusions, physical disturbance began. Owing probably to the pushing upwards of a deeply buried igneous mass, a general folding of the region was caused, and this resulted in the formation of a complicated series of faults. The lines of faulting have since served as channels along which chemical changes, notably the conversion of limestone into dolomite, have been effected by hot-spring waters. The ores, which are chiefly lead and zinc sulphides carrying silver, are chiefly found, in association with barytes, quartz and dolomite, at the intersection of two or more faults, and the theory is advanced that solutions ascending along one of these channels were precipitated by solutions that circulated along the other. The ore deposits have been laid open by erosion, it being estimated that since the beginning of disturbance 15,000 feet of sedimentary rocks have been removed.

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[1] Minutes of Proceedings Inst. C.E., vol. cxxxi. p. 289.

In mining and metallurgical methods Aspen has led the way in many improvements. Of late years, since the largest and richest bodies of silver ore have been worked out, the system of leasing the whole or parts of a mine to individuals or to groups of miners has become common. The production of the district from 1881 to 1895 inclusive amounted to 49,233,574 ounces of silver.

B. H. B.

The Repair of the Ölsnitz Colliery Shafts. C. Wurst.

(Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen, 1899, p. 95.)

At the Vereins-glück Colliery at Ölsnitz in the Zwickau coal-field, the coal is won by two shafts 40 metres apart, which were sunk to the base of the coal measures, a depth of 636 metres, at different times between 1871 and 1877 in No. I shaft, and 1877 and 1885 in No. II shaft; 55 metres being in the coal measures principally shales, and 545 metres in Permian strata, consisting of alternations of slaty clays, sandstones and conglomerates, the softer clayey beds being most abundant in the lower part of the section between 252 and 545 metres. Both shafts are rectangular and of the same breadth, 2 metres clear, but No. I is 5·93 metres long, and divided into four compartments, while No. II is 3·6 metres long, and has only three divisions. With the exception of 45 and 30 metres of depth respectively below the surface where curved brick walls 20 inches thick are used, the whole of the ground was secured by timbering up the ordinary square frame, the frames being set 1 metre apart, and lined with plank spillings. No thrust was observed during the sinking, nor was any expected, but from the defective arrangements for trapping the water in the upper levels, the clayey beds began to press in the timbering, which was further deteriorated, especially in No. II shaft, by the return air coming from a district where underground fires were common, so that it was necessary to replace it with a more durable lining. This was done principally by substituting for the timbers frames of I-iron, No. 15 standard German section, laid on the flat, and spaced 0·5 metre apart, which are carried at intervals of 4 metres by bearers of old railway rails laid flange upwards. The sides between the frames are closely lined with 120-millimetre round wooden props. Below 540 metres, however, closely set timber frames, forming a complete rib, are used. The complete repair of No. I shaft extended over a period of 8 years, 1887 to 1895, and similar repairs had been part carried out in No. II, when, on the 23rd September, 1894, the remaining timbering collapsed, and the shaft was blocked with the fallen ground to within 260 metres of the surface, the upper portion being protected by a strong bed of conglomerate at that level. As it was considered better to reopen the shaft than to put down a new one in another place, it was filled up with small waste from the coal

workings to prevent further collapse, and then treated as a new sinking, the ground being secured by iron framing of a somewhat heavier section than that previously used. The heaviest falls were found between 262 and 525 metres; the horizontal section of the hollows varying in places from 17 to 113 square metres, while the normal section of the shaft is only 10·6 square metres. In these places the iron lining was secured by timber platforms and frames bearing against the solid ground. The heaviest of these structures was in the pocket, between 372 and 392 metres, which had a maximum width of about 50 feet, and required struts of more than 12 metres in length, the details of which are very fully given in the Plates illustrating the Paper. Below 525 metres the original lining was found to be uninjured, and when the shaft was reopened in May, 1897, the provisional lining, though the heavily broken ground was replaced by curved brick walling from 1 metre to 2 metres in thickness, was carried upon bearing arches in the harder conglomerate beds, the dimensions being reduced to 3·6 metres by 1·8 metre. The brickwork is carried back to the solid rock, and any irregular hollows remaining are filled with small waste rock rammed tight. Below 525 metres, where there is no good foundation for masonry, the spaces behind the iron lining are filled with concrete. The ladders and changing platforms in the footway shaft have been entirely renewed in iron. The repairs of the shaft were completed in 3 years and 3 months for £13,086, or about half the time and cost that would have been necessary for putting down a new shaft.

H. B.

On the Relation of Surface Subsidence to the Thickness of Worked-Out Coal-Seams at Zwickau. C. Menzel.

(Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen, 1899, p. 147.)

The workings of the Zwickau collieries, which were originally commenced in the open country, have now reached the suburbs, and are approaching the centre of the town, at depths varying from about 200 metres (656 feet) to a maximum of 800 metres, with the result that many buildings have been disturbed by settlements of the surface. Observation on the rate of settlement at different points, eighty-two in all, have been carried on systematically since the year 1885 in order to establish if possible the relation between the amount of subsidence and the depth and thickness of the seams. A selection of these observations is given in the Table accompanying the Paper, from which the maximum subsidence in 12 years seems to have been 2,164 millimetres (85·2 inches) at a point where three seams had been worked out at depths between 202 and 302 metres. At the greater depth of 500 metres it was only 233 millimetres (9·17 inches). By the use of stone and earth packing for filling the excavations the settlement

is reduced, but not entirely prevented, as the packing is, by the pressure of the superincumbent ground, reduced to about one-half of its original volume, as stowed in the workings. The relation between the surface depression and the thickness of the seam, as deduced from the observations, varies between 1 : 1 and 1 : 7, but in the larger number of instances it ranges about 1 : 2; whence it may be stated that when coal seams having a total thickness M are removed at depths of several hundred metres from the surface, the probable depression of the surface to be anticipated will be about one-half of the thickness, or $S = \frac{1}{2}M$. For shallow workings a larger fraction must be adopted, but for depths between 350 and 400 metres the relation between settlement S, thickness M, and depth T in metres, may be expressed as follows:—

$$S = \frac{T + 350}{350\,M}$$

For greater depth the Author considers that 400 will be preferable to 350, as probably more correct.

H. B.

Mechanical Haulage at the Zwickau-Oberhohndorfer Colliery.

I. Treptow.

(Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen, 1899, p. 43.)

This is a detailed description, very fully illustrated, of one of the largest haulage plants on the Continent. The collieries, which cover an area of about 500 acres, are worked from three shafts, placed near the centre of the field from 600 yards to 800 yards distant from each other, and of the respective depths of 442 metres, 287 metres and 300 metres. The principal and deepest shaft, No. I, is of unusually large size, a rectangle of about 6½ feet broad and 33 feet long and divided by intermediate walls into three sections, of which the central one serves for pumps and footways, while those on the outside are fitted as independent drawing shafts each with its own engine; the heaviest tonnage lifted in one day in November 1898, being 2,985 tubs of 18 cwt. gross and 12 cwt. nett load, in No. I, 182 tubs in No. II, and 498 tubs in No. III shafts, or together about 2,200 tons nett load. The extreme distance of the workings from the shafts is about three quarters of a mile. The substitution of mechanical haulage for hand putting and horse haulage was commenced in 1880, and at the end of December 1898, the total length of lines at work was 17,030 metres (rather more than 10½ miles), 9,920 metres being underground and 7,110 metres at the surface; the longest single length of line is 2,550 metres underground and 1,400 metres at the surface. The haulage agents in use are endless ropes and chains, worked at the surface

by steam power and underground by air at 3½ atmospheres pressure. The engines for the latter purpose are necessarily small, owing to the heavy pressure of the ground, the cylinders varying from 7 inches to 10 inches in diameter and the power for each line between 10 HP. and 15 HP. The average haulage rate is from 40 metres to 50 metres, with a maximum of 63 metres per minute. At first the endless-chain system was mostly used, but at the present the overhead endless rope is preferred, the relative proportion of the different systems in use being as follows:—

	Metres.
Eleven overhead endless-rope lines	12,740
Two ground " " "	1,700
One shunting rope line	1,400
Two endless-chain lines	1,120
One endless-chain lift (incline of 7½ degrees)	70
	17,030

The ropes used are 14 millimetres in diameter made up of wires of 1·2 millimetre, with the exception of that used for marshalling railway wagons, which is of 16 millimetres with wires of 1·6 millimetre. The weight of the former is 0·75 kilogram per metre. The 14-millimetre link chains weigh 4·4 kilograms per metre and cost about twice as much as the ropes. This will explain the preference given to the latter, which, however, are more rapidly worn out, having an average life of little over a year, while chains may easily reach to five years. The average cost per ton-kilometre hauled is 1·86*d.* by the chain and 0·88*d.* by the overhead-rope system. The saving effected by the substitution of the endless rope for horses in marshalling loaded wagons is very considerable, the cost per ton-kilometre having been reduced from 1·1*d.* to 0·19*d.*, corresponding to a total saving of £1,122 on the tonnage despatched in 1897.

H. B.

Aërial Ropeways. E. Sobo.

(Berg- und Hüttenmännische Jahrbuch der k. k. Bergakademien, 1899, p. 369.)

This Paper, which covers nearly 100 pages and is illustrated by 136 drawings, was published in Hungarian in 1898, and has been translated into German by L. Litschauer. Wire ropeways present many advantages, especially in hilly districts, and their use is constantly extending in mining and metallurgical districts. The first ropeway built on technical principles dates back to the fifteenth century. In 1644 the Dutch engineer, Adam Wybe, erected a ropeway at Danzig for the transport of earth. Hemp ropes were used, and these ropeways consequently had a small capacity and were not durable. The invention of wire rope by

Albert of Clausthal in 1833 led to the further development of the ropeway as a means of haulage. It was not, however, until 1870 that appreciable progress was made. In 1871 Baron F. Ducker at Bochum, and in 1877 Hodgson in England, built double ropeways in which one line carried the full buckets and the other the empty ones. In the Hodgson system the supporting rope is an endless one, whilst in the Ducker system the two supporting ropes are fixed and there is an endless rope for hauling the load. Almost all ropeways are now constructed of these two types, the Ducker or German system, which has been considerably improved since 1870 by Bleichert, Otto, Obach and Pohlig, being that generally used on the Continent. The various types of carrying rope, hauling rope, attachments, boxes, buckets or wagons, coupling apparatus, terminal stations and shunting arrangements are described in detail, and full instructions are given for setting out and designing ropeways.

B. H. B.

The Development of the Freiberg Blast Furnace.

H. Kochinke.

(Jahrbuch für das Berg- und Hüttenwesen im Königreiche Sachsen, 1899, p. 107.)

The use of the blast furnace as the principal reducing appliance for lead ores has been characteristic of the Freiberg smelting works from the earliest times (the mines are reported to date back to A.D. 1160), and although it was for a time supplemented by the Welsh reverberatory furnace in the concentration of argentiferous coarse metal, this application was only in use for 15 years (1852–1867), and now the system followed depends upon perfect calcination of the ores, with the utilization of the sulphur and arsenic contents, and reduction in large water-jacketed furnaces of the Pilz form. The oldest recorded form of furnace in the sixteenth century seems to have been about 5 feet high, about 3 feet 9 inches broad, and 4 feet 9 inches deep, worked with a single tuyere and closed hearth, the melted products being tapped at intervals into an external basin, where lead, regulus and slag separated by gravitation. This was followed by the so-called Krummofen, which had an open fore-hearth, with slag run on one side, and a tapping basin at a lower level for the metallic products on the other; the term krumm, or crooked, having reference to the circuitous path provided for the metal, and not to the shape of the furnace stack, which was straight and square in plan. In the eighteenth century the first of the so-called semi-high furnaces was introduced. They were about 6½ feet in effectual working height and trapeziform in plan, the longest wall being on the blowing side, and the section was slightly enlarged in the region above the tuyere. The weight of charge smelted was about 35 cwt.

daily. With the introduction of coke as fuel in the nineteenth century, the furnace known as the single furnace was raised to about 10 feet, and its working capacity to 72 cwt. daily, and this, when provided with a second tuyere and a mid-feather wall, carried about half-way down the stack, in the modification known as Wellner's double furnace, which is of the same height, but about one-half broader than the single furnace, smelted about 10 tons daily. The Wellner furnace held the principal place for about 20 years, when it was superseded by the Stolberg furnace, which, retaining the prismatic form of stack, contracts regularly from the throat downwards, having a smaller hearth plane than the Wellner and four tuyeres, allowing a more rapid rate of driving, the working effect being raised to 15 tons daily. This was the last of the furnaces enclosed between walls; it was succeeded by free standing forms, which at first were made octagonal in plan, but in 1865 the circular form, with eight tuyeres and closed hearth, with a Darby cylinder gas collector, was adopted. This smelted 50 tons daily, with a consumption of 8½ per cent. of coke, and could be kept in blast for a year. In 1872 the circular furnace was improved by Pilz by the addition of a water-jacket in the region of fusion, and, after various modifications, a standard size was adopted, about 5 feet in diameter and 25 feet to 27 feet high, with twelve tuyeres, which smelts about 60 tons daily, the coke carrying from fourteen to fifteen and a half times its weight of burden. A further increase in diameter up to 6½ feet, and twenty instead of twelve tuyeres, has been adopted in a new furnace which was blown in on the 25th October, 1898, and has been found to work advantageously, the output being increased from 10 to 38 per cent., according to the nature of the materials treated, the fuel consumption being somewhat lessened, and the blast furnace reduced from 15 to 25 millimetres to 10 millimetres (0·39 inch).

In the latest modification of the Pilz furnace, adopted at the Pertusola works, a double series of tuyeres are used, twelve being placed equidistant around the hearth, about 30 inches above the furnace bottom, and twelve others alternating with them about 4 inches higher. This is found to work advantageously with rich charges which have not been completely calcined, and has also been experimentally adopted at Freiberg.

H. B.

Purification of Furnace Gases. H. Wedding.

(Verhandlungen des Vereins zur Beförderung des Gewerbefleisses, 1899, p. 185.)

At the Kotterbach iron mines, in a rich agricultural district of Upper Bohemia, the ores—consisting almost entirely of carbonates—are roasted before being sent to the blast furnaces, with the

object of driving off the carbonic acid and of so saving about 33 per cent. in cost of carriage.

The sulphurous and mercurial vapours given off in the roasting process having done considerable damage to animal and vegetable life in the neighbourhood, and the agricultural industry being at least of equal importance with the mining industry, a plant was put down to condense and absorb these noxious vapours. The gases are led from the tops of the roasting furnaces, and by means of steam injectors sent forward through a system of towers, which are constructed of timber, having three storeys with open timber floors thickly set with blocks of limestone. A spray of water extending over the whole area of the tower is constantly dropping through the successive floors from a high-level tank. The gas enters at the bottom of one tower, ascending against the stream of water through the spaces between the limestone blocks to the top, then to the bottom of a second tower, to go through the same process, after which it is allowed to escape into the atmosphere. Condensation of mercury and its compounds, and also of arsenic and antimony compounds contained in the gases, takes place owing to the temperature being reduced by the dripping water, which also absorbs part of the sulphur oxides.

The remainder of the sulphur oxides displaces the carbon dioxide of the limestone, forming sulphites and sulphates of lime. The mercury—part of which is left in the gas trunks, the greater part however going through the towers and being collected in settling ponds—is purified and its value is sufficient to cover the cost of running the plant.

Full details of the processes with copious analyses, and also Plates showing the arrangement of the works, are given with the Paper.

W. B.

Water-Supply to Paris from the River Avre and its Tributaries. FÉLIX BRARD.

(Mémoires de la Société des Ingénieurs Civils de France, October, 1899, pp. 397–486.)

Owing to the peculiarities of its geological formation, the watershed of the river Avre and its tributaries—which is situated some 60 to 80 miles west of Paris, and during the last ten years has been furnishing part of the water-supply to the capital—presents a variety of characteristic features. Chief among these are the disappearances altogether of the river itself and of some of its tributary streams at certain points of their course; the reappearance of their waters in springs lower down the valley; and the prevalence of natural gully-holes and of fenced funnel-shaped hollows. What is here meant by a gully-hole—locally called *bétoir*, a corruption of *boit-tout* or "drink-all"—is a hole started from the top and worked downwards, either by surface water in

the meadows wearing its way through the layer of turf or peat that covers the porous gravel of the subsoil; or by a stream wearing its way down through its sandy clay bed into the same porous ground beneath. These gully-holes are only a few square yards in area, of no particular shape, and of no great depth, say from 4 to 16 inches only. A fenced funnel on the contrary is a large subsidence started from below, resulting from the formation of an underground cavity, excavated by the flow of subterranean water, into which the superincumbent ground has ultimately run down in the shape of a funnel, with sides sloping as steep as 45° and even up to 60°, according to the natural slope of excavations made in the silicious clay in which the subsidence has taken place. The funnels are from 8 to 20 feet deep or more, and from 4 to 30 yards diameter. Being surrounded by a hedge of brambles or bushes, or otherwise fenced off from the rest of the field in which they occur, these conical hollows are locally called *mardelles-entonnoirs*; *mardelle* is the equivalent of the commoner *margelle*, which signifies a kerb, or a breast-high wall surrounding the mouth of a well or of a disused mine shaft. A review which the Author gives of the results of examining the water from wells in the silicious clay and in the marl, from gully-holes in the river and meadows, from fenced funnels, from porous and impervious ground, from the subsoil of the valleys, and from the springs, has enabled him to compile geological sections, and to calculate the quantity of marl dissolved annually; this is considerable, and explains the formation of underground cavities of such magnitude that the district is in a state of gradual subsidence.

Dealing next with the hydrography of the Avre, and of the numerous brooks which together with the river Vigne fall into it, he shows that much more than half of all their water finds its way into the subsoil. Particulars are added of experiments made with colouring matter by Mr. Ferray, chemist of Evreux, which have proved that there is communication between the water going down the gully-holes in the river and in the meadows, and the water in springs. The remedy is to do away with the gully-holes, as was done in 1897 by the administration of the Ponts et Chaussées in regard to those in the river Avre and in the brook Saint-Maurice; those in the meadows ought equally to be done away with. Chemical and microscopic examination has shown that the Avre water varies considerably in its contents after rain, owing to the water from the brooks mixing with that from the springs; the increase in the number of microbes corresponds closely with the rainfall up to about $\frac{1}{8}$ inch in a day. From whatever sources the water-supply of Paris is obtained—the Vanne, the Dhuys, or the Avre—the public health is at present endangered whenever the water becomes turbid; there is then the greatest increase in the quantity of organic matter and bacteria. Owing to the progress of science in all directions during the ten years that have elapsed since the Avre water was brought to Paris, the Author urges that it is high time improvements should be effected

without delay, for diminishing the dangers of epidemics. The water ought to be made to filter through the ground; and impure water ought everywhere to be prevented from finding its way into the subsoil. For the latter purpose cement strengthened with internal iron trellis has been found advantageous for lining the beds and banks of streams; other methods might also prove suitable.

A. B.

The Purification of Water by Ozone. GEORGE A. SOPER.

(Engineering News, New York, 19 October, 1899, p. 250.)

Ozone, an allotropic form of oxygen, having three atoms to the molecule, instead of two, has long been known as a powerful oxidizing agent. It owes this property to its readiness to give up the extra atom of oxygen, especially when in the nascent state, *i.e.*, during its formation. The usual method of production is by the silent discharge of electricity through oxygen, especially in the presence of moisture. The Author describes various experiments on the purifying effect of ozone upon water, due to its strong germicidal power. Ohlmueller experimented upon water from the River Spree, using a direct current and induction coil capable of making 3 milligrams of ozone per second. He was able to kill 3,717,000 anthrax bacilli in ten minutes with 90 milligrams of ozone, and 12,247,000 typhoid bacilli in two minutes with 19·5 milligrams. He concluded that ozone acted as a powerful destructor of bacteria, provided the water did not contain too much solid matter. The Author also describes experiments by Baron Henry Tindal and himself upon water. He finds that ozone has the faculty of removing unpleasant organic smells. Its action upon water is purely chemical, the impurities combining with oxygen and forming oxides. The water should first be filtered to remove coarse matter held in suspension.

A. P. H.

Automatic Valves for Water Mains. A. VAN MUYDEN.

(Le Génie Civil, vol. xxxv., 1899, p. 317.)

The Author describes a valve the invention of which is due to Mr. Piccard, which automatically cuts off the supply of water from the mains, in case of a rupture of any of the pipes. The invention has been used with great success at Geneva, where formerly several inundations have been caused through the bursting of the high-pressure supply pipes carrying water to the reservoirs connected with the town service.

The essential part of the arrangement is a concave valve connected to a balance weight, which is heavy enough to keep the valve lifted as long as water is on both sides of it. The overplus of weight is proportioned to the maximum speed at which the water is required to be taken off at the lower end of the pipes, formulas for the determination of which are given. If from any cause a pipe should burst, thus causing a more rapid flow of water, the pressure on the concave valve overcomes the balance weight and the valve closes. When once closed the valve cannot again be opened until the pipes are full of water, for which purpose a by-pass is provided. A hydraulic brake on the dash-pot system prevents the valve from closing too rapidly. Four figures in the text illustrate the valve and its application.

H. I. J.

The Nature and Applicability of the Biological Processes for Sewage Purification. Dr. DUNBAR.

(Deutsche Vierteljahrsschrift für öffentliche Gesundheitspflege, 1899, p. 625.)

An account is given of the history of the so-called biological processes for the purification of sewage-water, and the Author states on the authority of Schmidtmann, that the movement in this direction, which during the past few years has made such important progress in Germany, is still on the increase, and he gives much credit to the experiments of Schweder at Grosslichterfelde, which are practically based upon Cameron's employment of the septic tank at Exeter. The only difference consists in the provision by the former inventor of what is termed an aerating shaft, to which shaft, however, little value is attached. Dibdin's process is also noticed, and his claim to employ pure cultures of suitable micro-organisms for the rapid decomposition of the impurities is examined. The Author explains why he prefers to use the term "oxidation processes," instead of "biological processes," which latter nomenclature is indeed misleading. A general classification of the various systems follows, and a detailed account is given illustrated by means of diagrams, of the plan and mode of carrying on the experimental works conducted at Hamburg by the Author. The character of the sewage is discussed, and full analyses are given of the composition of the raw sewage and of the effluent water. From certain of the trials here recorded it appeared possible by the oxidation process to deal with the fouled water equivalent to a population of from 25,000 to 30,000 persons on an area of 2·47 acres for months together, without apparent exhaustion of the beds, and entirely without chemicals, and to produce an effluent which was superior in point of quality to that of any sewage irrigation works known to the Author, with the solitary exception of those at Paris. In conclusion, the opinion is expressed that the oxidation process is at least equal in value to the septic-

chamber process, and is at the same time cheaper and more rational. Under certain circumstances, however, owing to local conditions, the use of the septic chamber may be preferable.

G. R. R.

The Epidemic of Typhoid Fever in Löbtau in the Year 1899.

Dr. W. Hesse.

(Zeitschrift für Hygiene, vol. xxxii. pt. 3, p. 345.)

In the middle of July, 1899, a sudden outbreak of typhoid fever occurred in Löbtau, a suburb of Dresden, with a population of about 34,000 inhabitants. Within a few days about 100 persons, living in many different houses, were attacked in such a way as to lead to the conviction that the disease germs must have been introduced by means of some article of food. Milk and meat being freed from suspicion, the water-supply was the only remaining probable source of infection. On comparing the cases it became evident that one of the two watercourses, the Gorbitz brook, had been the means of spreading the epidemic. Plans of the town are given, and the situation of the infected areas with the numbers of cases, together with information as to the water-supply, are fully indicated. The detailed analyses of each of the streams, with particulars as to the mode of distributing the supply from the waterworks, follow, and it is shown that the germs of typhoid fever were probably introduced into the water in the middle of June. On the 15th June the rainfall was heavy, and some excrementitious matter was then doubtless washed into the watercourse. The mode of investigating the blood of the patients is described, and of the 247 cases recorded, 184, when examined by Widal's serum-test, gave positive results, forty-three yielded negative results, and the remainder, with certain exceptions, were doubtful. Thus in by far the larger number of cases this method of diagnosis proved reliable. Amongst the conclusions it is stated that the number of cases of infection diminished in proportion as the germs of typhoid fever became reduced in the water-supply.

G. R. R.

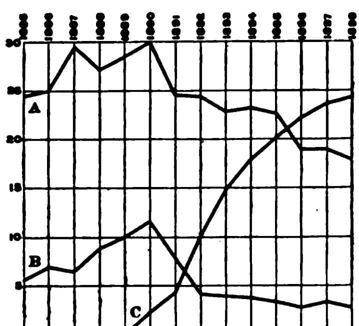
Influence of the Establishment of Sewers on the Diminution of the Death-Rate of the City of Buenos Aires.

Gabriel Carrasco.

(Boletín Demográfico Argentino, vol. i., August 1899, p. 31.)

Before the construction of the waterworks was commenced in 1869, the city had no water supply beyond that furnished by wells, rain-water tanks, and by distribution in carts direct from the river.

Year.	Population, including Suburbs.	Death-Rate per 1,000, all causes.	Death-Rate per 1,000 from Typhoid Fever.	Houses Drained per 1,000 Inhabitants.	Houses with Water Supply per 1,000 Inhabitants.	Inhabitants using sewers per 1,000.	Inhabitants using Water Supply per 1,000.
1869	177,787	33·6	0·97	..	4	..	..
1870	186,320	31·6	0·33	..	8	..	..
1871[1]	195,262	106·3	0·82	..	12	..	..
1872	204,634	27·7	0·64	..	13	..	..
1873	214,453	27·5	0·63	..	13	..	..
1874	220,000	32·4	0·75	..	15	..	..
1875	230,000	29·4	0·56	..	16	..	..
1876	200,000	26·4	0·67	..	21	..	..
1877	215,000	25·8	0·49	..	21	..	..
1878	234,029	23·6	0·48	..	21	..	..
1879	257,440	26·3	0·57	..	22	..	..
1880	270,708	26·1	0·60	..	25	..	..
1881	289,925	21·7	0·74	..	25	..	..
1882	315,761	22·7	0·67	..	23	..	..
1883	340,375	21·7	0·53	..	22	..	..
1884	365,302	22·3	0·53	..	22	..	..
1885	384,492	24·2	0·54	..	23	..	345
1886	400,951	25·0	0·68	..	24	..	360
1887	437,875	29·6	0·64	..	26	..	390
1888	455,167	27·2	0·85	..	29	..	435
1889	523,452	28·2	0·97	..	31	..	465
1890	547,144	30·0	1·15	4	34	60	510
1891	535,060	24·3	0·76	8	45	120	675
1892	554,713	24·1	0·39	18	53	270	795
1893	580,371	22·4	0·37	27	56	405	840
1894	603,012	22·7	0·36	30	60	450	900
1895	663,854	22·5	0·31	30	58	450	870
1896	712,095	19·2	0·29	31	55	465	825
1897	738,484	19·2	0·35	32	54	480	810
1898	765,744	17·7	0·28	32	53	480	795
1899[2]	795,000	17·1	0·14	32	53	..	..



A. General death-rate per 1,000.
B. Death-rate from typhoid fever per 10,000.
C. Number of houses sewered in 1,000's.

[1] Yellow fever caused 15,000 deaths.
[2] Information received since the preceding figures were published in the *Boletin*.

For the 20 years following, during which the waterworks were gradually extended, the death-rate varied from 22 per 1,000 to 30 per 1,000, it being noticeable that the continual increase in the number of houses supplied with water did not lead to any regular diminution in the death-rate.

The average mortality of each five years of the period was respectively 27·3, 26·3, 22·9, and 26·8. This bears out the contention that, as soon as water can be obtained from town mains, its use is increased, and, in the absence of adequate means of drainage, causes the subsoil to become polluted, neutralizing any advantage obtained from the purer water supply.

The death-rate tended to show an increase towards the end of the above period, the mean of the whole (omitting 1871, a year of an exceptional epidemic) was 25·8, and in the year 1890 the death-rate was 30 per 1,000, or among the highest on record. In that year the use of the sewers began, and since then the connections have been extended to all the houses within the area to which the works extended, and concurrently with this there has been a steady diminution of the death-rate, notable not only for its importance but for its continuity.

This reduction is due to the more general elimination of the most potent cause of death, namely, the retaining of organic matter within the houses. In 8 years there have been saved 25,000 lives, and it may be said that the sacrifices made in the construction of the sewage works have been amply recompensed.

It is calculated that, at the present time, there are, for every 1,000 inhabitants, 795 who make use of the water supply, and 480 who live in houses connected with the sewers. Of the remainder, 205 obtain their water from wells, rain-water tanks, or direct from the river, while 520 live in houses whose drainage still infects the subsoil; but since these latter are found only in the new suburban neighbourhoods, their existence has not, so far, had any detrimental effect upon the public health; there is, however, urgent necessity for extending both the water service and the sewers to these districts, in order that they shall not be the cause of the death-rate again increasing.

It is significant that the deaths from typhoid fever were reduced to one-third of their former amount as soon as the sewers were brought into service.

Buenos Aires now occupies the nineteenth position as regards death-rate among ninety of the largest cities of the world.

The Table and diagram on p. 341 form a summary of all the information contained in the report, from which the accompanying diagram is also extracted.

R. C. P.

Distribution of Gas under High Pressure. F. H. SHILTON.

(Engineering News, New York, 5 October, 1899, p. 219.)

The Author expresses surprise at the long continuance of low-pressure gas distribution for domestic purposes. Whereas water is frequently distributed at 100 lbs. to 300 lbs., and steam in crowded streets at 200 lbs. to 300 lbs. per square inch, gas still remains at the low pressure of 2 inches to 3 inches of water, or about $\frac{1}{10}$ lb. per square inch. The Author urges a high pressure in order to increase the carrying capacity of pipes, and considers the saving in outlay so effected would more than pay the expense of compressing, and of the possible increased strength of piping. He does not advocate taking the high-pressure gas into houses, but would provide each house with a reducing valve and meter, which he maintains would cost about 12*s.* to 16*s.* per customer. Other things being equal, the carrying capacity of a pipe varies as the square root of the pressure, and increasing the pressure fourfold would double the capacity. The Author proposes to overcome the increased leakage in existing mains by fitting a split cast-iron sleeve over the joints. He also advocates the use of wrought-iron pipes, experience showing that their supposed tendency to rust is over-estimated. He gives instances of wrought-iron piping being found in sound condition after 12 years' service underground.

A. P. H.

Electrical Developments in the United States in 1899.

MARCEL DELMAS.

(Mémoires de la Société des Ingénieurs Civils de France, November, 1899, p. 635.)

The Manhattan peninsula, constituting the city proper of New York, is so long and so narrow—12 miles to 16 miles by not more than 2 miles to 3¼ miles wide at the utmost—and the congestion of the traffic is so continuously increasing, that the numerous tramways running from end to end, and the overhead elevated railways carried above them along the same streets, are now about to be supplemented by an underground line following the same general course in a tunnel under the roadway, the construction of which is about commencing. To meet this approaching competition, the elevated railways are intended to be worked by electricity, instead of by steam locomotives; and owing to the enormous excess of traffic in the morning and afternoon, just before and after the ordinary business hours, the problem corresponds with that of an electric-lighting station, which requires power enough to surmount the peak in the curve of the daily supply. At the present time 40 miles of elevated railway are working, equivalent to 110 miles of single line; there are 1,000

carriages running, of 50 seats each, and performing 43 million carriage-miles per year. The number of carriages is to be increased 30 per cent., and a central generating station is to be constructed, supplying 64,000 HP. in economical working, and capable of rising to 96,000 HP. By quicker starting it is expected to save 15 minutes on each journey, which at present occupies about 50 minutes; the increased speed will enable each carriage to convey 16 per cent. more passengers per day, while electric traction will allow of six carriages per train, instead of five. The number of trains will remain about the same as at present; later it is hoped to run them at shorter intervals, notwithstanding their increased speed. The generating station will comprise eight units, each of 8,000 to 12,000 HP., distributing a triple high-tension current to eight sub-stations, where rotary transformers will furnish a continuous current of 600 volts to the third rail. The boilers will be Babcock and Wilcox, with forced draught, burning slack on self-stoking grates. In each unit the dynamo will be carried on the driving shaft midway between a pair of compound engines, each pair working cranks at right angles and at 45° to the other pair, thus giving eight impulses per revolution; at 75 revolutions per minute it will yield 5,000 kilowatts. The station will be large enough to allow of adding four more units, making twelve in all, which altogether will occupy a floor space of 50,000 square feet; there will then be about $1\frac{1}{3}$ kilowatt or 2 HP. per square foot, and $\frac{3}{4}$ square foot per kilowatt or $\frac{1}{2}$ square foot per HP. The relative merits of making each individual carriage in the train a motor-car, or of employing a separate electric locomotive for the entire train, are discussed by the Author, who however does not intimate whether this question has yet been decided, or how.

The metropolitan electric tramways in Boston, started in September 1898, run barely 12 miles underground out of their total working length of 155 miles; the underground portion however carries one-seventh of all their traffic, which is so great as to exceed the present accommodation of some of their stations. These have platforms 200 to 260 feet long, allowing five or six independent cars to set down and take up at the same platform without incommoding one another. When a score of trolleys are simultaneously grating along the electric wires overhead, the din is deafening. The tunnel is well ventilated, and its walls are whitewashed; the various mechanical appliances, as well as the electric ventilators, appear amply sufficient. The total power supplied from the several generating stations is 31,000 HP. Last year's working was 173 million passengers and 29 million car-miles, or six passengers per car-mile. Apart from electric locomotives, there are 2,350 electric cars, or 15·2 per mile worked. At Park Street underground station two or three cars start per minute during the busiest time, which is between 5 and 6 o'clock in the afternoon; here this one hour's traffic amounts to about 12,000 passengers, being one-fifth of the entire day's traffic at this

station, and 90 per cent. of the total traffic at all the stations during this same hour. Exclusive of taxes and interest on capital, and of rent of the underground portion, which was constructed by the municipality of Boston, the cost of working, including general expenses, is 10·65*d.* per car-mile. A second electric line is about to be constructed, which is to be an overhead or elevated railway on a metal superstructure.

With a view to flattening the curve of the daily output from electric-lighting stations, and to getting rid of the peak that occurs in it every evening, it has been the general endeavour to secure a good day load by supplying electricity for motive power to small works and private houses at a reduced rate of charge. In America it appears now to have been found that in winter this practice, so far from flattening the curve, raises the peak still higher, because the peak of the lighting curve becomes in winter contemporaneous at about 5 o'clock in the afternoon with the peak of the power curve; and the two being superposed require additional generation or storage of power at the stations. In summer the same inconvenience does not arise, because the peak of the lighting curve then occurs so much later that the power curve has already fallen off considerably. To get over the difficulty, a double scale of charge has been established in Brooklyn, one of the suburbs of New York, by means of clock-meters, which obviate the necessity for a double wiring; they record the day consumption up to 5 o'clock at a charge of 4*d.* per kilowatt-hour for small consumers and 1*d.* for large, while for the evening consumption from 5 o'clock to 11 o'clock the charge recorded is from 7*d.* to 4*d.* according to the consumers' importance. Large consumers can thus work 8 hours a day for a year of 300 days at a cost of £7 per HP.: taking care to stop punctually at 5 o'clock, except so far as regards ventilators or feed-pumps or other appliances that have to run the whole 24 hours. At the outset the power supply was taken by 175 large consumers, who had previously generated their own electricity at less than 7*d.* per kilowatt-hour; these took the cheaper supply up till 5 o'clock, and then switched on their own instead for the 6 hours of higher charge; but their dynamos being now driven for so short a time, the cost of working became so much increased that they finally gave up generating for themselves, and took their whole current from the public supply. Shops also, which show a blazing front at night, but during the day were contenting themselves with gas as cheaper, have now abandoned gas, and taken advantage of the double tariff for electricity. The immediate effect of the plan has been to lower the peak of the curve in the Brooklyn station from 900 down to 700 kilowatts for an average output of 300 kilowatts; hence without increasing the maximum engine power the average output can now be raised to 500 kilowatts. In the business quarters of New York city the twofold rate of charge is unnecessary, because the consumption curve is fairly level during business hours, and uniformly low for the rest of the time. The high-tension distribution from Brooklyn

has been extended 15 miles to the seaside summer resorts, which compensate for the falling off in the town consumption at this season, with the result that the monthly gross receipts are kept the same throughout the year within about 10 per cent. The clock-meter for the twofold charge costs only £5 more than an ordinary meter; for a small consumer, using five to fifty incandescent lamps or 1 to 2 HP., the clock-meter will cost about £8 to £9; and about £20 for a large consumer using 300 to 400 lamps or 80 to 100 HP.

Electricity is being more and more employed for warming tramcars. It is also used for the whole of the cooking operations in a restaurant which daily at noon serves 300 dinners to the office staff of the General Electric Works. The cooking utensils are distributed throughout the dining hall within reach of everyone. The cleanliness is unrivalled. Judging from the small size of the lead fuses, the current of electricity cannot be large.

At present the employment of electricity in connection with chemical processes is mainly associated with the great power station at Niagara. This was built for supplying 50,000 HP. by means of ten sets of turbines and dynamos, of 5,000 HP. each; six sets were already at work in 1898, two more were added in 1899, and the remaining two are expected to be completed this winter (1899–1900). A second building for another 50,000 HP. has now been ordered, which will take its water from the same tunnel; the latter was one of the heaviest items in the original outlay, and was made large enough for 100,000 HP. The manufacture of carbide of calcium, which proved a failure on the first attempt in 1897, made a fresh start in 1898, taking 4,000 HP.; a larger factory has just been constructed, which is already taking 15,000 HP., with the prospect of rising to 25,000 HP. The first aluminium factory, taking 4,000 HP., has been supplemented by a second of 8,000 HP. capacity; the latter is deriving its power from a private fall, instead of from the Niagara station. A second factory is in progress for the electrolytic production of caustic soda and of chloride of lime for bleaching, and will take 3,000 HP. A factory of 1,000 HP. is also about to be started for making graphite, which sells at £14 a ton for refractory linings and mouldings. A new electrolytic lead works will take 1,000 HP.; and the prosperous carborundum factory for making abrasives is now taking 2,000 HP. A high-tension supply of 15,000 HP. for lighting and tramways is transmitted to Buffalo, which has a population of 300,000; here a large receiving station has been constructed for transforming 7,000 HP. for lighting. The average consumption for lighting is at present 4,000 HP.; the maximum is provided for by accumulators of 3,000 ampere-hours, which have cost £14,000. The tramways take about 3,000 HP. The rest of the Buffalo power is supplied to the elevators at the large granar[illegible] shipbuilding slips, and to the repairing shops, situ[illegible]ore of Lake Erie. The curves of the daily o[illegible] Niagara station are remarkably horizontal,

showing no peak, and scarcely any perceptible fluctuations; the reason is that the electro-chemical factories work night and day, while the Buffalo electric-lighting and tramway requirements are equalised by their ample batteries of accumulators. The Niagara charge to large consumers is about £4 per HP. per annum for a single alternating current of 2,200 volts; the triple current of 11,000 volts at Buffalo is charged at about £6 per HP. per annum for 24 hours' supply per day. Besides the principal Niagara station, there is also a smaller, belonging to other owners, for which the water power available is scarcely more than about 100,000 HP.; it is confined for room, and is at present disposing of only 15,000 HP., half in water power and half in electricity; the turbines are of 2,000 HP.

Electrical construction is in the hands of two huge concerns, the General Electric and the Westinghouse Company, which have entered into a mutual agreement not to compete with each other. The Westinghouse comprises electrical machinery, steam engines and boilers, and air brakes. The General Electric, which is the larger and keeps always abreast of new discoveries, has works at Lynn, Harrison, and Schenectady, covering 44 acres and employing 9,000 hands; they are now making stationary transformers of 1,800 kilowatts, and are about to construct dynamos of 8,000 HP. for working the elevated railway in New York by electricity. At Los Angeles [1] their electric transmission of power from a distance of 75 miles has proved a great success. They have also employed voltages of 20,000 up to even 40,000 without any accident as yet. At Salt Lake City a single network of wires distributes the current from two stations 46 miles distant, which work synchronously. The substantial financial position of the General Electric is set forth, which enables them to hold the leading position in electrical construction.

A. B.

The Enlargement of the Zurich Electricity Works.

H. Wagner.

(Schweizerische Bauzeitung, 1899, pp. 43 *et seq.* Figs.)

The original plant of the Zurich electricity station consisted of four dynamos, each of 200 kilowatt capacity, but the increased demand for current in 1895 and 1896 clearly proved an extension necessary, as in the winter 1896–7 all the machines were fully loaded. It was at first thought that the extension could best be actuated by water-power, but it was finally decided to put in steam plant, with three dynamos and the necessary boilers. Delays occurred and the new plant was only set to work in the winter of 1897–8; meanwhile the question of supply of current to the tram-

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[1] Minutes of Proceedings Inst. C.E., 1899, vol. cxxxviii. p. 543.

ways had arisen, and it was decided that provision ought to be made for this also upon the original site. In the future it is expected that water-power will be used for driving the whole or part of the plant. The new plant is of the polyphase type and gives 2,000 volts, with fifty periods per second; it can also be used to give single phase current at the same potential.

The three dynamos were built by the Maschinen Fabrik Oerlikon and are of the inductor type. The 750-HP. machine has bar winding, and the two 1,000-HP. machines have bobbin winding, with stationary armatures all run at 100 revolutions per minute, and the magnet rings act as fly-wheels.

The 750-HP. steam-engine was built by Escher Wyss and Co., and is of the Corliss condensing type with Frikart valve gear and shaft governor, which also acts as a fly-wheel. The dynamo is coupled direct to the engine.

The other two engines were built by Sulzer Brothers, and each develops 1,000 HP. at 100 revolutions per minute; they have Porter governors and work condensing. The steam consumption of the latter engines at 1,000 HP. was found to be 12·85 lbs. per I.HP. per hour.

The additional boiler plant consists of seven double boilers, each consisting of an upper and lower cylinder; the lower part is 16 feet 5 inches long by 7 feet 9 inches in diameter, with two furnaces, while the upper part is 12 feet 9½ inches long by 7 feet in diameter; the working pressure is 150 lbs. per square inch; the upper vessel has no furnaces but is provided with tubes only, through which the hot gases pass. Behind each boiler a Schwörer superheater is placed, which raises the steam to a temperature of 482° F. The grates are designed for burning gas coke. All the boiler plant was supplied by Escher Wyss and Co., and three of the boilers are fitted with special travelling grate-bars by Münckner and Co., and an economiser is to be fitted in the main flue hereafter. The main switchboard is described in detail. A transformer substation serves for the supply of current to the street railways on the left bank of the River Limmat, including the Sonnen and Limmat quay lines. The building is designed for four 200-kilowatt, direct current, rotary transformers, of which three are now installed. The station is under the charge of the electricity department, which delivers current through meters to the tramways department. Each transformer consists of a 2,000-volt polyphase motor, direct coupled to a continuous current dynamo giving 550 volts, and the Author gives details of the special windings. The apparatus runs quite silently—an important feature, as the substation is in the centre of the town. The switching apparatus is fully described. The total cost of the central station was £43,200, and of the substation £9,240.

E. R. D.

The New Electricity Station in Granada.

(Revista de Obras Publicas, 1899, p. 87. Figs.)

In the year 1893, a private concern, the General Electricity Company of Granada, set up an installation of 70 HP., but naturally this small plant was of very little use. The company, however, acquired a concession for the use of the water-power of the Genil, and they employed Mr. Manuel Grusat as consulting engineer, the power to be used was about 2,000 HP., produced by a fall of 340 feet. The contract was let to the firm of Alioth of Basle, Switzerland. The new central station is situated at Pinos-Genil, about 6·25 miles from Granada, and about 3 miles higher up the gorge the supply canal branches off the river; the average volume of the water is about 70·6 cubic feet per second, but in spring, when the snow melts, it is from 15 to 20 times greater. The canal is about 3 miles long, and is open, except where tunnels were found necessary; there are twenty of these, the principal one being 196 yards in length. Details are given of the construction of the weir and canal, which has a fall of 2·8 per 1,000. The canal supplies at present one turbine tube 870 feet long. The first part has a fall of 33 per cent., the latter part 63 per cent.; its diameter is 3 feet $3\frac{3}{8}$ inches, and it passes 24·5 cubic feet of water per second, with a velocity of 3 feet 3 inches.

The station is designed for 5 sets each of 350 HP., all on the ground floor; at present only three are installed. The turbines are of the horizontal shaft type, and were built by Piccard and Pictet of Geneva; each is coupled direct to an alternator. A detailed description is given of the automatic regulation. The alternators are by Alioth, and each develops 54 amperes at 4,200 volts; the frequency is 52·5 periods per second and the exciter is fixed upon a continuation of the main shaft. The main switchboard is arranged so that the alternators can be put in parallel.

The line consists of two bare copper wires, each 0·312 inch in diameter, which permit the delivery of 350 HP. to a distance of 6·25 miles, with a loss of 8 per cent. The insulators are of the triple bell type, and the wires are at a height of 28 feet above the ground; there is also a telephone line on the same posts. There are at present twelve transformer stations, and the distribution is on the 3-wire system with 125 volts on each side. The new power plant has caused a decrease in price of current of 30 per cent.; the present rate is 54*s*. per annum per 16-candle-power lamp, or 1*s*. per kilowatt-hour. The whole plant was built and erected in 6 months.

E. R. D.

The Fuel Economy of Electric-Light Engines.

R. C. CARPENTER.

(Engineering News, New York, 12 October, 1899, p. 234.)

The Author gives results of tests made on different classes of engines used for electric plant. The conditions of work are very different from those where the load is steady, as the rapid variations tend to materially affect the average efficiency, from a thermo-dynamic point of view. In the case of simple non-condensing engines with slide valve, the average results obtained were 34·3 lbs. of steam, and 4·63 lbs. of coal per I.HP. per hour. The minimum steam-consumption was 27 lbs. corresponding to normal loads, while an increase or reduction of load, increased the steam-consumption. In the case of compound non-condensing engines with slide valves, the tests were carried out at the same working pressure as the above, though the comparison is somewhat unfair. The Author finds that there is a saving of 9·4 per cent. of coal and 5·5 per cent. of steam as compared with the simple engine. Compound engines, however, require 40 per cent. more steam for variable than for normal loads, as against 25 per cent. for the simple engines, under which conditions, therefore, the advantage of compound engines seems doubtful. In the case of compound condensing engines the tests gave average results of 22·7 lbs. of steam and 3·25 lbs. of coal per I.HP. per hour in the case of slide valves, and 18·2 lbs. and 2·36 lbs. respectively for Corliss engines. Based upon these results, the Author gives a Table showing the cost per I.HP. per annum, including first cost of engine and labour, but excluding land, buildings, &c., which do not depend upon the class of engine.

The result of these calculations shows a large balance in favour of the high class Corliss engine, the cost being £2 17*s.* per I.HP. per annum, as against £6 10*s.* 9*d.* for the simple non-condensing type.

A. P. H.

The Sag and Tension of Line Wire. CARY T. HUTCHINSON.

(Engineering News, New York, 31 August, 1899, p. 130.)

The problem presenting itself in hanging a line wire is to calculate the sag and tension, so that the latter may not exceed a certain given maximum at the given temperature. It is usual to neglect the effect of the elasticity of the copper, which causes considerable error. A decrease of temperature produces a shortening of the wire, resulting in a diminution of sag. Such diminution, however, is less owing to the elastic stretch of the

wire than would be the case were the wire inelastic, and the wire is thus subject to smaller increase of tension due to lowering of temperature. The Author treats of the relieving effect of elasticity and gives formulas and curves showing the effect of temperature and elasticity separately and jointly, also a numerical example showing the error due to neglect of elasticity. He points out that this error leads to undue allowance of sag, and shows that the wire might be strung tighter than is now the rule with sufficient margin of safety.

A. P. H.

On the Nature and Cause of the Phenomena of the Coherer.

THOMAS TOMMASINA.

(Archives des Sciences Physiques et Naturelles, 1899, p. 133.)

The Author's experiments have shown that the increase of conductivity in a coherer consisting of metallic filings is due to the formation of continuous chains of particles welded together at their points of contact by the heat generated by the passage of a series of sparks. Further experiments show that these chains may be produced without previous contact between the electrodes and the filings.

The Author sprinkles filings on a board fixed horizontally between the poles of a Ruhmkorff coil, and finds that on working the brake by hand vertical chains of filings are formed at every discharge, reaching from the board to the electrode above it. In distilled water the phenomena are still more striking, chains more than 20 centimetres long being produced by the action of the automatic brake. If the current is reduced to a certain point a number of chains rise simultaneously in the liquid by a series of rapid movements until one of them touches the electrodes, when all the rest fall to pieces. As long as the current passes the chain that has made contact is not easily broken, but if the current is interrupted the slightest shock destroys it. By placing some filings in the bottom of a U-tube containing distilled water and putting the electrodes in the two branches of the tube it is shown that the chains grow simultaneously in both directions towards the electrodes. By a similar arrangement the direction of the lines of flow between two electrodes at opposite sides of a dish of water may be demonstrated.

G. J. B.

The Thermophone.

(Engineering News, New York, 17 August, 1899, p. 109.)

This instrument is used for indicating temperatures at a distance, and is the joint invention of Messrs. G. C. Whipple and H. E. Warren. It depends upon the increase of electrical resistance in metals, due to a rise in temperature, a form of Wheatstone bridge being employed to measure resistances and so temperatures. If R, r, a, A, be four resistances joined in endless series in the order named, and if one pole of a battery be joined to the junction of r and a, then if a galvanometer joined across the other two sides of the square is undeflected, the relation holds good that $\frac{R}{r} = \frac{A}{a}$. In the thermophone R and r are two coils of dissimilar metals, such that their temperature coefficients of electrical resistance are different, while A and a are varied relatively by a contact sliding along a piece of German silver wire, and bisecting it at ordinary temperatures. The two coils R, r, are placed in the spot of which the temperature is required. Instead of a galvanometer a telephone receiver is used, which enables the most delicate currents to be detected until the bridge is in perfect balance. The two resistances A, a, can be arranged in a circular form round a dial, the sliding contact being a pointer pivoted at the centre, and sliding upon the wire at the outer end. If the connecting wires between the distant coils and the German silver wire are of small resistance, the instrument can be made of large range and of great sensitiveness, it being possible to read to $\frac{1}{10}°$ F. with a dial of 8 inches diameter. The Author gives formulas by which temperatures may be calculated from the known coefficients of the dissimilar metals, and suggests resistances to give the best results, *i.e.*, a suitable range of temperature combined with due sensibility.

A. P. H.

Brick-testing in the years 1895–97. M. Gary.

(Mittheilungen aus den koniglichen technischen Versuchsanstalten zu Berlin, 1899, p. 121.)

The Paper contains in tabular form the results of tests on bricks made during the three years 1895–97 at the Royal Testing Laboratory. The bricks are divided into four groups, and the compressive strengths varied as follows:—

	Kilograms per Square Centimetre.	Tons per Square Foot.
Klinkers	764 to 198	700 to 182
Hartbrandsteine	508 „ 207	465 to 188
Verblender	706 „ 175	645 to 160
Hintermauerungsteine	459 „ 65	418 to 59

From which it will be seen that the compressive strength alone does not serve to determine the group to which a certain species of brick belongs.

Various points in connection with the tests are discussed. It is pointed out that the drying of a brick previous to testing, if performed at a temperature of about 30° C., requires about 26 days, while if a temperature of 80° C. to 100° C. be used the drying is complete in about 5 days.

In experiments on bricks subjected to alternate freezing and thawing, it was noticed that frost enables the brick to absorb a greater quantity of water, the water in the act of freezing being forced deeper into the pores of the brick than is the case when immersion in cold water is alone employed. The results of the experiments on this point are clearly shown by a set of curves.

In testing cubes built up of bricks and mortar in respect of the influence of the age of the mortar joints on the strength, it appears that, after two weeks' or three weeks' age, there is no further increase of strength with age. The methods of carrying out the experiments exert a much greater influence on the apparent strength than do many other factors. In particular, the newer methods in use at the Royal Testing Laboratory give more reliable results as compared with the older methods. A number of bricks were tested by both methods, and the deviation of the individual results from the mean strength is classified in groups, each group corresponding to a 10 per cent. difference. One hundred and sixty-eight individual tests were made by the old methods, 155 by the newer methods; 31·6 per cent. of the individual tests by the newer methods gave results between 100 per cent. and 110 per cent. of the mean strength, 22 per cent. of the individual tests lay between 90 per cent. and 100 per cent. The corresponding figures for the older methods were 17·2 per cent. and 18·4 per cent. The frequency curves for both methods is plotted and shows clearly the superiority of the newer methods.

A. S.

Earth Pressure against Retaining Walls. A. A. Steel.

(Engineering News, New York, 19 October, 1899, p. 261.)

The Author describes experiments carried out during the summer of 1898. A pit was dug 8 feet deep, 11 feet long, and 7 feet broad. A wooden partition was built across it, 6 feet 6 inches from one end, the larger volume of the pit being filled with earth, and the other occupied with measuring apparatus. The depth was increased to 15 feet 6 inches by a bin which was built up on the surface, the width of earth being sufficient to eliminate any effect of end conditions.

In the wall were two openings about 12 inches square, the lower edges being respectively 6 inches and 30 inches from the

bottom of the wall. Into these openings boards were fitted having some play. These were kept in place by a lever, of which the horizontal thrust could be measured. The boards were suspended vertically from wires attached to a cross-head, and connected to another lever. It was, of course, necessary to keep the boards in the same plane as the wall, and central with the holes. This was arranged for electrically, a displacement either horizontally or vertically completing a circuit, which actuated a motor and so tightened or loosened spring balances attached to the outer ends of the levers. The Author gives results of experiments upon varying conditions of earth as regards dryness and angle of surface, and compares these with the theoretical pressure deduced from formulas by Professor Merriman.

A. P. H.

The Exact Design of Statically Indeterminate Frameworks.

F. H. Cilley.

(Proceedings of the American Society of Civil Engineers, October, 1899, p. 564.)

The Author sets himself the task of showing the superiority of statically determined over indeterminate framework. The statical analysis of frameworks with superfluous bars shows them to be inferior in economy and strength while not superior in stiffness to the best designs without such bars. He points out that the stresses in these bars are determined by their precise lengths, but as a matter of fact, in any existing structure, these lengths are never known with anything like exactitude; for with a modulus of elasticity of 30,000,000 lbs. per square inch a steel bar 10 feet long whose length is not known within $\frac{1}{1000}$ foot would not have its intensity of stress determined within 3,000 lbs. per square inch.

By taking the case of the simplest form of indeterminate framework subject to multiple loadings, and of a two-hinged arch under several loadings, the Author shows the practical impossibility of any general application of exact methods of calculation; also that any small apparent advantage, for particular cases of loading, of the indeterminate over the exact design would be neutralized by the temperature stresses, which affect the former but not the latter.

A. W. B.

The Relation of Failure to Manner of Application of Stress.

A. Föppl.

(Centralblatt der Bauverwaltung, 1899, pp. 527 and 541.)

The strength of a body is generally considered in the light of its behaviour under simple stresses, that is, stresses whose projections on to two of the three principal axes equal zero and which,

therefore, exert tension, compression, or shearing in one direction only.

As regards the "relation of failure to stress," otherwise the "strength" of bodies acted on by more complicated stresses and its measurement, little is known, and opinions differ widely. Of the older assumptions, the first took the governing stress to be the chief stress in any one direction and neglected the remaining stresses; with the second, the greatest proportionate extension, and with the third, the greatest shear was considered the chief factor. In Germany the second view is generally held, but the results attained by the few recent investigators do not confirm this view. In this connection the Author refers to the theories or experiments of Mohr, Wehage and Voigt, and then proceeds to give an account of a number of experiments carried out by himself.

The Author first sought to determine the effect on various bodies of equal forces acting from all sides; the pressure was applied by means of a liquid and reached 3,500 kilograms per square centimetre (50,000 lbs. per square inch). Cast-iron, copper, tin, lead, aluminium, stone, and wood, in pieces of various shapes, were tested. The weaker materials broke or became deformed, sandstone broke into laminations parallel to its natural bed.

In another series of experiments pressure was applied along two axes, the stress along the third principal axis being zero. The force was in most cases applied mechanically by an ingenious arrangement, which is shown. These experiments are compared with simple crushing experiments, and in this connection cement, sandstone and granite cubes, with greased ends, were crushed and found to show only from ¼ to ½ the strength of cubes with dry ends; they broke into prismatic, not pyramidal, forms.

Experiments were also made with circular metal plates, supported all round the edge.

The Author comes to no definite conclusion as the result of these experiments, but proposes shortly to deal with them in greater detail.

W. B.

Changes in the Volume of Portland Cement Mortar, with embedded Metal.

(Annalen für Gewerbe und Bauwesen, 1 December, 1899, p. 216.)

Reference is made to the experiments conducted upon armoured concrete in France in the Ecole des Ponts et Chaussées from 1886 to 1889, and in Germany by Meier and Schumann, and to the recent investigations of Considère on prisms of concrete having iron cores. The internal tensions which take place under these conditions are worthy of study, and require to be examined in connection with certain of the results obtained under the "Monier"

system of construction. Certain of the prisms used by Considère were of neat cement, and others were of cement concrete in the proportions approximately of 4 parts of quartz sand to 1 of cement. The prisms were in all cases 23·6 inches long, and the cross section of each was 2·36 inches by 0·98 inch. The core was an iron rod 0·4 inch in diameter. The proportion of iron to concrete in the cross section was thus as 1 : 17·2. Half the samples were immersed in water, and half remained in the air, and they were tested at intervals for increase or decrease in length. In each case parallel test pieces with and without cores were used for purposes of comparison. The expansion of the prisms without metal was in every case much greater than in the case of those with cores, and the tests, which extended over 9 weeks, are shown in a Table, the gain in length of the various test pieces being stated in hundredths of a millimetre per metre. It is stated that the use of the metal core impeded the expansion of the concrete, and caused tension in the case of the metal and compression in the concrete. Various estimates follow of the forces exerted to produce the observed results. The prisms kept in air contracted in the first instance and then slowly expanded, the total expansion exceeding that of the immersed samples.

G. R. R.

The Heating of Concrete during Setting. G. Baire.

(Le Génie Civil, vol. xxxv., 1899, p. 300.)

It is well known that Portland cement while setting gives off heat, sometimes to a considerable extent: but the phenomenon is rarely observed in laboratory experiments, or where small quantities only are used. The Author describes some experiments carried out by him on a concrete engine-bed made in the works of the "Société des Ciments" at Boulogne. The total volume of the concrete, excluding the foundation, was about 139 cubic metres (181·8 cubic yards). It was run in very soft in about 26 hours, and the method employed for taking the temperatures was by the use of 4 thermometers, which were placed in the recesses left for the holding-down bolts. Two of these thermometers were of the ordinary type and two registered maximum temperatures. Observations were taken during a period of 23 days, at the end of which time the temperature of the mass was practically that of the air. During the observations the exterior temperature varied from 0° C. to 11° C. The highest temperature, viz., 29° C., was reached on the seventh day, that is, some time after the concrete was completely set. Diagrams are given showing the disposition of the thermometers, and a curve of the temperatures.

H. I. J.

Composite Girders of Iron and Cement.[1] F. Chaudy.

(Mémoires de la Société des Ingénieurs Civils de France, October, 1899, pp. 487–496.)

In its most elementary form the Author regards a composite girder of iron and cement as consisting of a pair of round iron bars, one forming the upper member and the other the lower, tied together at the required distance apart by round wire ties at right angles to them, and the whole then embedded in concrete, which takes the place of diagonal struts in compression; the adhesion of the concrete to the iron skeleton plays the part of the riveting in an ordinary girder made wholly of iron. For larger girders two or more pairs of the round iron bars which constitute the elementary form of the girder are spaced alongside of one another, and instead of round wire ties flat iron strips are bound round them, and the butt ends of the strips are bolted together with a cover strip; the whole is embedded in concrete. For still larger girders a pair of angle-bars, placed back to back so as to form a T section, are employed for the top member, and another pair forming an inverted ⊥ for the bottom member; and the flat iron strips uniting them are riveted between each pair, and half the width of each strip is turned over the flat of each angle-bar at top and bottom; then the whole is embedded in concrete. For all these modes of construction the Author points out that the calculation of the bending moments and breaking loads of the composite girders—whether simply resting on their bearings at each end, or fast fixed in their end supports, or built as arches or as cantilevers—differs in no essential feature from that employed for a similar girder constructed wholly of iron. The compression upon the concrete in contact with the iron skeleton, and the longitudinal force tending to separate them, are considered; as are also the tension upon the ties, and the proper spaces between them in different parts of the girder. In girders in which the top and bottom members are not parallel to each other, and in cantilevers, the quadrilateral spaces or panels between the ties should be everywhere of such a length that the diagonal lines of compression shall make angles of 45° with the ties. In comparison with a girder wholly of iron, there is no saving in making one of iron and cement if the parts have to be riveted together. While taking the place of the diagonal struts subjected to compression, the concrete also preserves the whole of the iron against oxydation.

A. B.

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[1] Minutes of Proceedings Inst. C.E., vol. cxxxix., pp. 435–438.

Concrete-Steel Bridge Construction. EDWIN THACHER.

(Engineering News, New York, 21 September, 1899, p. 179.)

Concrete-steel is a steel structure embedded in concrete. The chief physical quality enabling such structures to exist is the fact that the thermal coefficient of expansion is practically the same for the two materials, otherwise a change of temperature would cause shearing stress at the line of juncture. When used as a symmetrical beam, with the centre lines of steel and concrete coincident, the amount of load borne by each would be in proportion to its modulus of elasticity, and inversely proportional to its moment of inertia. It is, however, usual to design the steel part to be capable of taking the whole of the bending stresses in case of faulty concrete. Another advantage of this combination is the protective effect of the concrete. An instance is cited of freedom from rust after 400 years under water. It has also been successfully used for bridge piers, and has been found very efficient in withstanding floods. A concrete-steel bridge designed and patented by the Author has the following characteristics. Two pairs of steel bars are used to form a beam, each pair consisting of two horizontally parallel bars, connected at intervals, while the two pairs, one below the other, have no connection, except the concrete, in which the whole is embedded. The bars thus take the place of the flanges in an H girder, whilst the concrete performs the function of the web and takes the shearing stress, which it is easily capable of doing. The Author quotes instances of several bridges built upon this system.

A. P. H.

Influence of Span in Transverse Tests of Cast Iron. DR. R. MOLDENKE.

(Engineering News, New York, 17 August, 1899, p. 103.)

In transverse tests of cast-iron bars the American Foundrymen's Association Committee have chosen the distance between supports of 12 inches. This was selected, after much consideration, being convenient to handle and cast. This comparatively short span is also advantageous in that an increased length makes the test less severe, with a given speed of testing, since the time element makes itself felt. Again, in determining the behaviour of the material under sudden stresses, a 12-inch span is found to be sufficiently long to give trustworthy results. A series of experiments with varying spans was carried out by the above committee as follows. Six different patterns were made of a bar 2 inches square and 16 inches long. Six castings were then taken from the same metal, and the whole operation repeated five times in

order to get fair average results. The specimens were tested transversely by bending up to rupture, the length of span being gradually increased from 6 inches to 16 inches. The results showed that rupture took place at internal breaking stresses, which decreased almost uniformly as the span increased. There was also a marked and unexplained diminution of bending stress for a 10-inch span, of which phenomenon the Author gives several possible solutions.

A. P. H.

Strength of Cast-Iron Columns. J. B. NAW.

(Engineering News, New York, 31 August, 1899, p. 134.)

The Author gives a method for calculating the safe load for cast-iron columns in terms of sectional area, and $\frac{l}{d}$, or relation of length to diameter. Diagrams are given based on Gordon's formula, and are those used in the building laws of New York, Boston and Chicago. The curves are plotted with lbs. per square inch as ordinates, and the quantity $\frac{l}{d}$ as abscissas. Three diagrams are shown, giving ultimate breaking stress, safe stress for round columns, and safe stress for square columns. The first two diagrams show, in addition to curves as used by the three cities mentioned, the results of experiments on cast-iron columns obtained by Professor Burr. This shows great divergence from the calculated ultimate load; the error being greatest for small values of $\frac{l}{d}$, and meeting the other curves at a value of $\frac{l}{d}$ of about 30. In the calculations for safe load, New York allows 16,000 lbs. per square inch compressive stress, corresponding to a factor of safety of about 5, while Chicago and Boston allow only 10,000 lbs. per square inch, or a factor of safety of 10.

The Author gives numerical examples, solving the problem of total safe load for given columns.

He also gives Tables of sectional area and radius of gyration for various sizes.

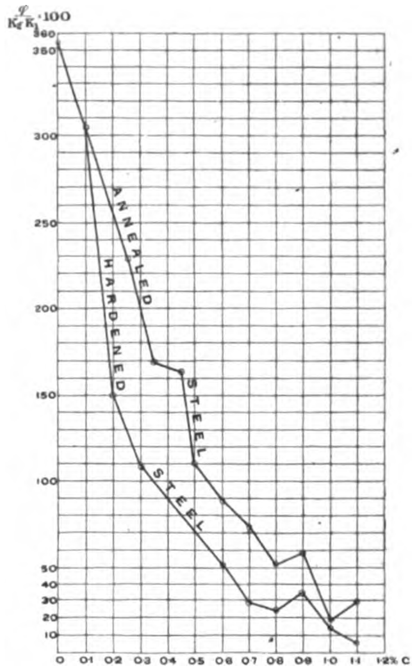
A. P. H.

Toughness of Steel. A. K. SHOKALSKI.

(Morskoi Sbornik, January, 1900, p. 172.)

In an article in the *Gornui Jurnal* (Mining Journal), No. 8 of 1898, on the tool steel of the Putilov Works, by Engineer Surzhitski, he deals with the question of the qualities of good samples of this product. Taking toughness of a material to mean the resistance it offers to the severance of its particles beyond the limit of

elasticity, he defines the toughness of steel by the difference between the stresses at the point of rupture and the limit of elasticity. The present Author considers that the ratio of this difference of stresses to the extension corresponding to it furnishes a basis for a correct measure of the toughness of steel. He gives a Table of the results of numerous experiments—mostly Russian ones—setting forth the stress at the elastic limit and that at the point of rupture, the difference between these two stresses, the percentage of elongation for this difference, and the ratio of this difference to the elongation, for hardened as well as annealed steel, containing quantities of carbon varying from 0·1 per cent. to



1·1 per cent. Calling the stress at the elastic limit K_1 and that at the point of rupture K_2, in tons per square inch, and the extension between K_1 and $K_2 = \phi$ per cent., the ratio $\frac{\phi}{K_2 - K_1}$ is found to vary inversely as the percentage of carbon in the steel, and is considered a good basis for the measure of toughness of steel. These results are summarised graphically in a diagram from which the annexed is drawn. The sudden change or reversal in the direction of the curves at the point of saturation (8 per cent. to 9 per cent. of carbon) is very marked. The point of saturation forms a line of demarcation, on either side of which

the grouping of the component parts of the steel is essentially different. The several component parts of steel, as discovered by microphotography and chemistry, are described. The presence of various foreign substances serves to lower the point of saturation. As the percentage of carbon increases beyond the point of saturation the steel becomes less homogeneous in structure, its hardness continues to increase, whilst its toughness changes rapidly into brittleness, and the objectionable tendency to crumble before change into the liquid state is increased. The Author thinks it would be desirable to verify the data in the Table, and to supplement them by filling up the blanks it contains at present.

C. H. M.

Impact Tests of Steel. S. Bent Russell.

(Engineering News, New York, 16 November, 1899, p. 323.)

In specifications for steel and iron most engineers require the material to stand some impact test, to prove its power to withstand sudden shock. Until recently these were either transverse or compressive tests. The Author found the former to give unfair preference to mild steel, and accordingly designed a machine for making impact tests for pure tensile stress. The machine is fitted with a heavy pendulum supplied with a steel striking surface at its centre of percussion. The specimen to be tested is fixed at one end while the other end is attached to a forked arrangement, which receives the blow from the pendulum. To calculate the resilience of the specimen, the amount of work necessary to break it is observed. The vertical height between the centre of gravity of the pendulum at the commencement of its swing, and at its lowest point, at which the impact occurs, is measured. The swing then takes place, the specimen is broken, and the pendulum continues its swing, due to the remaining kinetic energy. The height of this continuing swing is noted, and thus, allowing for certain necessary deductions, the work done in breaking the specimen can be found. The specimens tested hitherto have been nicked, so as to expose a sectional area of very short length, to the force of the blow. Thus the tests are only comparative, since the distribution of stress in such a short nick is a subject not yet fully understood.

A. P. H.

Expanded Metal. P. Chalon.

(Mémoires et Compte Rendu de la Société des Ingénieurs Civils, July, 1899, p. 21.)

The manufacture of expanded metal was first introduced into France in 1898, and has developed very rapidly; six Golding machines being now at work in the manufactory at Saint-Denis.

The Author describes fully the manufacture of the expanded metal by this machine, which cuts the meshes by successive strokes of toothed cutters, the metal being opened or expanded into a trellis shape as it leaves the machine. Each machine weighs about 28 tons, and absorbs from 5 to 8 HP., according to the thickness of the plate upon which it is working. The steel which is found most suitable for this work contains the least possible amount of carbon, about 0·7 per cent. of manganese, and must be as free as possible from sulphur, phosphorus and silicon. It has a tensile strength of from 22 tons to 25 tons per square inch, and an elongation of 25 per cent. to 26 per cent. The sheets must be manufactured from ingots as soft and as pure as possible, and made either by the Siemens-Martin or basic Bessemer process.

The second part of the Paper deals with the applications of this metal for building purposes, such as flooring, partitions and lattices. When used with concrete the strength is about double that of armed concrete made with round metál bars. The applications described possess particular advantages, which the Author summarises under the heads of economy, solidity and lightness, hygiene, and resistance to fire.

The Paper is illustrated with 22 Figures in the text and 1 Plate.

H. I. J.

The Collapse of the Chicago Coliseum.

(Engineering News, New York, 14 September, 1899, p. 162.)

The structure was to have been composed of twelve steel arches, hinged at crown and shoes, with longitudinal tie-rods connecting the two shoes under the flooring. Each arch was 150 feet span and 66 feet high. The longitudinal connecting links between the arches consisted of four lattice girders on each side, running from end to end, and one at the crown to support the skylight. In addition, each of the end arches was to have been attached to the neighbouring arch by cross bracing. The initial cause of the disaster was the removal of the derrick by which the structure was erected. In the process a pulley was fixed to the crown of one of the arches, and the resultant pull had a considerable horizontal component. As the two halves of the arch merely abutted against each other this resulted in their being pulled out of line, and led to the successive collapse of all the arches. At the time of the accident the four longitudinal girders on each side were *in situ*, but not the one at the crown, nor the cross bracing at the ends.

Twelve men were killed and as many injured, and there is little doubt the disaster would have been avoided had the hauling rope been run through a snatch block on the floor, and so carried it up vertically to the crown. It is thought that much of the material can be used again.

A. P. H.

The General Levelling of France. C. LALLEMAND.

(Annales des Mines, vol. xvi., 1899, p. 227.)

The first systematic series of lines of level were run in France by Bourdaloue, who, in 1847, made the investigation for determining the relative levels of the Mediterranean and the Red Sea. It was carried out between 1855 and 1863, and included a network of lines of a total length of about 5,000 kilometres, which were referred to the mean sea-level at Marseilles as a zero point. In 1878 a commission was established for the new series upon a much more extended scale, which is now in progress of completion under the Author's direction. This is intended to enclose the whole country in forty-two polygons, each corresponding to a department, ten of which terminate at the frontiers or on the coast, the remaining thirty-two being closed and averaging 600 kilometres in length. These are lines of the first order, and follow the main lines of railway. Each mesh of this network is cut up into five or six smaller ones, said to be of the second order, which are partly run along railways and partly on roads, the work being done with somewhat less precision than in the fundamental series. These again are divided into shorter series of the third, fourth and fifth orders, which, on account of their lesser importance, are done by more rapid and economic methods. The total length of the levelled lines when completed will be about 800,000 kilometres, and upon the results a systematically contoured map will be based. The expenditure is not to exceed twenty millions of francs (£800,000).

The levelling instruments used vary in sensibility with the different orders of lines; for the first and second series the radius of curvature of the bubble tube is 50 metres, for the third and fourth 30 metres, and for the fourth and fifth 20 metres. A system of total reflecting prisms is used to enable the position of the bubble to be read from the eye-piece end of the telescope simultaneously with the reading of the staff. The levelling staves used also differ with the different series, those for the first and second order are fitted with compensation bars of brass and iron, the differences in length being observed three times during the day, the variations due to changes of temperature during the day amounting to several hundredths of a millimetre per metre, the maximum being attained in the afternoon. In the lines of the third order plain staves of 3·2 metres long, divided upon two faces, with their zero points at the opposite ends, are used, and in the fourth and fifth ordinary elongating rods with one divided face, which can be used up to a total length of 4·2 metres on very steep roads.

The distance between the points observed does not exceed 140 or 150 metres, the position of the instrument being not more than 1 metre from the central point upon the line. Three determinations

are made, one for each of the three micrometer lines in the eye-piece, and the operation is afterwards repeated in the reverse direction. In the second order lines distances up to 170 metres, and in those of the third, fourth, and fifth orders, up to 200 metres are permissible. The observations made on the field are sent every day to the office, where they are compared and reduced, and if the apparent differences are too great the work is repeated. The divisions on the levelling staves are carried down to 2 millimetres, but no special accuracy is sought for, it being preferred to apply the corrections, found by very careful comparisons with standards made in the office, to the observed results.

Up to the present time the first or fundamental network of 12,400 kilometres, and the second of 16,300 kilometres are completed; the third, of 15,000 kilometres, is well advanced, and the fourth and fifth have been commenced, and about 74,000 bench marks have been fixed. The probable error of the determinations in the series completed is—

For systematic error	0·12 to 0·18 mm. per kilometre.
Accidental	0·79 mm. per kilometre.

The average closing errors in the polygons averaging 550 kilometres in length is ± 60 millimetres.

Taking into account the systematic error, the probable error in the difference of level found between Marseilles and Dunkirk does not exceed 60 millimetres.

The cost per kilometre has been as follows:—

Lines of the first order	35 francs.
„ second „	28 „
„ third „	22 „
„ fourth „	18 „

The Bourdaloue survey cost 55 francs per kilometre.

H. B.

Atmospheric Observations by means of Kites.[1] MARCEL DELMAS.

(Mémoires de la Société des Ingénieurs Civils de France, November, 1899, pp. 667–671.

At Washington Observatory in the United States the kite employed for atmospheric observations is of cubical shape, each edge measuring 6½ feet; it can rise about 10,000 feet or 1⅞ mile, and at this height is held by 2½ to 3 miles of wire. It keeps in balance without a tail, and weighs 7·7 lbs.; it carries also a box containing the recording apparatus, which weighs 3·3 lbs., bringing up the total weight to 11 lbs.; and it presents to the wind an effective surface of about 75 square feet. The wire controlling it

[1] Minutes of Proceedings Inst. C.E., 1900, vol. cxxxix. p. 444.

is steel pianoforte wire 0·028 inch diameter, on which a strong wind produces a pull of from 90 to 110 lbs., and on rare occasions 130 lbs.; in an ordinary wind the pull is from 20 to 30 lbs., as shown by a dynamometer at the bottom of the wire. As a safeguard against too strong a wind, the wire is made fast to the kite at a higher point than that from which the kite flies; and to this lower point it is attached by a rather finer wire, which ordinarily takes the whole of the pull, but breaks in too strong a wind, and thereby transfers the pull to the higher point; the kite then lies on the wind, and the observations can be continued with it in this position; or else, the pull being thus reduced, the kite can be drawn down without risk, in view of an approaching gale. The wire is carefully greased daily, and kept free from the slightest speck of rust. Rarely is the wind not strong enough to fly the kite, at any rate in the higher regions of the atmosphere. How the kite is sent up is not explained; for hauling it down, the drum is rotated by one or two men, or by a small steam-engine. In making an observation the readings taken are the time, the pull on the dynamometer, the length of wire paid out, the angle which the wire makes with the horizon as it leaves the drum, its azimuth, and the angle of elevation of the kite itself above the horizon. Tables giving the corresponding height of the kite are calculated up to 3·1 miles of wire and a height of 1⅞ mile or about 10,000 feet, for an altitude above the horizon varying from 26° to 64°, and for an inclination of the wire at the drum varying from 0° to 45°. In this way, and by means of the recording apparatus in the kite, the state of the atmosphere can be ascertained at any time and at any height within the limit. In the Washington kite the recording apparatus registers the pressure, temperature, and moisture of the air, and by means of an anemometer the velocity of the wind. The recording apparatus of the anemometer consists of an electro-magnet controlled by very light small dry cells of chloride of silver. A recording apparatus on the ground registers photographically the sunshine or cloud, and also the temperature of the sun's rays. The Author regrets that the study of the electrical condition of the atmosphere has not yet been entered upon by means of kites, being unaware that this is already being done.[1] A similar kite procured from Washington is now in use in France at the Trappes Observatory (Seine et Oise) under the direction of Mr. Teisserenc de Bort; and others at Nantes and in Germany.

A. B.

[1] See an article on "The Electrification of the Atmosphere," in *Engineering*, 5 January, 1900, pp. 1–3.

The Meteorological Observatory on the Schneekoppe. SAAL.

(Centralblatt der Bauverwaltung, 1899, p. 578.)

The Schneekoppe rises 1,605 metres (5,265 feet) above sea-level. The observatory is erected on the summit, and consists of cellars, used for storage purposes, ground and first floors, containing kitchen, living and bedrooms, and, over all, the observatory tower.

As the building was to be habitable throughout the year, it was necessary to take due precaution against storms, snow and cold. The foundations and outer cellar walls were built in stone from the mountain top, and the party-walls and arching in brick. The upper walls of the building were constructed of a timber framework, built in with corkstone;[1] on the outside, covered with 3 centimetres (1·18 inch) thick boarding, then with two layers of asphalt paper, and, finally, with small shingles; on the inside, covered with plaster slabs, which, in the hall and kitchen, are painted with an oil colour, but in the living rooms are covered with felt, and papered.

The wooden floors are filled with sand and ceiled with plaster slabs over a thick layer of felt. The windows are double, with wooden shutters which can be opened and closed from inside. Part of the roof is of galvanized iron and part solidly constructed of timber and concrete.

The hall and staircases are warmed from the cellar; each room has a slow combustion stove. The lightning-conductors are earthed, 500 metres below the summit, in damp ground.

Four steel stays or guys and iron verticals built into the walls help to secure the stability of the structure.

The cost of the work was 40,000 marks (£2,000).

W. B.

On the Secular Variations of the Inclination of the Compass. Dr. FOLGHERAITER.

(Archives des Sciences Physiques et Naturelles, 1899, p. 5.)

The Author describes his researches on the dip of the needle in ancient times. His method depends upon the fact that pottery formed of clay containing iron, in the process of baking becomes permanently magnetic, the direction of the lines of force coinciding with those of the earth's magnetic field at the time. He shows that in a house the magnetism of each brick is independent of its orientation in the house, but depends upon the position it occupied

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[1] *Korkstein* = cork chips consolidated into bricks, the binding medium being either cement or tar accordingly as white or black bricks are desired.

in the kiln, and by means of a specially constructed furnace made absolutely without iron he proved that the action of the earth's field was sufficient to induce magnetism in the pottery baked in it. Although sufficient data have not yet been obtained to determine with certainty the declination of the needle in ancient days, its inclination, assuming the vases to have been stood upright in the furnace, is easily determined.

After describing the method of observation, he gives some of the chief results deduced from pottery of known period.

About eight centuries before the Christian era the angle of dip was small, but directed towards the south. Two centuries later it was zero. At Pompeii, about the time of the eruption, the angle of dip was 66°. The results of a large number of observations are shown graphically in a curve, which is sigmoid in shape, and covers the period from 800 B.C. to 200 A.D.

G. J. B.

The Odograph, for Fog-Signalling at Sea.

Capt. C. Arnaud.

(Bulletin de la Société Scientifique Industrielle de Marseille, 1899, p. 17.)

For steamers it is proposed to divide each quarter of the compass into four portions of 22° 30′, and employ the siren as an indicator of the main direction of the vessel's course whilst the precise subdivision is indicated by blasts of the whistle. Thus, a vessel steaming between north and east would give one blast of the siren followed by one, two, three or four whistles according as the course is 22° 30′, 45°, 67° 30′ eastward or direct east, and so on.

On the other hand, for sailing vessels, three sets of signals are considered sufficient, viz., one, two, or three blasts of the fog-horn according as the ship is sailing on the starboard or port tack, or before the wind.

The odograph consists of a graduated compass card inscribed with a large and small circle, the former in turn intersecting the centre of a number of smaller graduated circles corresponding to the above-named divisions of 22° 30′. Each small circle is provided with a movable indicator needle. The vessel's course is marked out by adjusting the central needle, and, on hearing the signal of an approaching vessel, the needle of the small circle corresponding to the quarter from whence the sound travels is set in accordance with the particular signal given, thus showing the relative direction of the two courses, and indicating the manœuvres necessary to avoid collision.

C. S.

The Orrechioni Submarine Look-out. L. FABRE.

(Bulletin de la Société Scientifique Industrielle de Marseille, 1899, p. 9.)

The appliance, which is intended to precede the vessel to which it is fitted, at a distance of 3,400 yards, and automatically give warning of any obstacles in the water, consists of a cigar-shaped cylinder about 23 feet (7 metres) long, by 20 inches (50 centimetres) in diameter, constructed of $\frac{1}{5}$-inch (5 millimetres) sheet aluminium, and containing an electromotor, which receives current (through a conducting cable) from the ship's dynamo and actuates a pair of screw-propellers.

The conical head of the cylinder contains the contacts for connecting the line wire with the electromotors, and is fitted at the point with a vertically arranged fork attached to a rod which is pushed forward by a spiral spring. As soon as the fork comes in contact with an obstacle this rod is forced backwards, thus breaking contact with the line wire and completing the circuit actuating an electric bell on board the vessel, and also making a second contact with the line wire, the result of which is to reverse the motors and move the cylinder astern until free of the obstacle.

The tapering stern end of the cylinder is strengthened by four longitudinal ribs, cut out at a point near the end to leave a free space for the screws. The total weight is about 24 cwt. (1,200 kilograms), the motors weighing about 1,980 lbs. (900 kilograms), the shell 440 lbs. (200 kilograms), and the screws, fork, and accessories about 220 lbs. (100 kilograms). For use in shallows, where submerged reefs, etc., are likely to be encountered, a vertical rod of greater length than the draught of the vessel can be attached to the signalling apparatus of the cylinder.

The conducting cables, two in number, are insulated with gutta percha, and provided with cork floats to keep them near the surface, the cylinder being also driven at a speed greater than that of the ship, so as to ensure the cables being kept taut and the cylinder itself maintained in the proper course. A series of contacts on each cable enables the impact of the automatic look-out of an approaching vessel on either board to be recorded in the engine-room, and the vessel's course modified accordingly.

C. S.

A Phenomenon observed on passing a Current through a Rarefied Gas. Prof. A. RIGHI.

(Il Nuovo Cimento, vol. x., 1899, p. 112.)

A battery consisting of 282 small accumulators is placed in circuit with a sensitive galvanometer, a high non-inductive resistance, and a vacuum tube containing nitrogen at 0·2 millimetre

to 0·3 millimetre pressure. One of the electrodes is a point, and the other either a disk or a ball.

The illumination of the tube is apparently continuous, and the deflection of the galvanometer measures the current that passes. Under these circumstances, if the position of the resistance in the circuit is changed, both the luminosity of the tube and the deflection of the galvanometer are altered in amount. The current is greatest when the resistance is placed between the exhausted tube and the positive pole of the battery, and least when it connects the negative pole with the tube. It is essential that the shape of the kathode should differ from that of the anode, and also that the added resistance should be large, *e.g.*, 30 megohms, and in order to obtain well-marked results the electromotive force should be only just sufficient to determine the passage of the current. Thus, for example, a current of 5·48 micro-amperes passed when the resistance was between the tube and the positive pole, and a current of 0·4 ampere when it was placed near the negative pole with a battery of 282 elements, while the addition of six more elements raised the current to 6·44 micro-amperes with the resistance near the positive pole, and 5·08 micro-amperes when it was inserted close to the negative pole.

Other forms of tube and different kinds of electrodes were tried, and also various gases, and the phenomenon was found to be general. The Author explains it on the hypothesis that such a discharge is not continuous but oscillatory.

G. J. B.

On the Contact Theory. Quirius Majorana.

(Archives des Sciences Physiques et Naturelles, 1899, p. 113.)

If two disks, one of zinc and the other of copper, are fixed facing each other a few centimetres apart, and each is separately earthed for a few moments, they will become charged to different potentials, the copper being negative to the zinc. Helmholtz pointed out that this condition is one of electrical equilibrium, and that no further flow of current can take place unless the capacity of the system is altered by varying the distance between the plates.

The Author has verified this statement by the following experiments.

The disks used, which were 15 centimetres in diameter, were connected with a Hankel electrometer, in which a fine fibre of silvered quartz was substituted for the usual gold leaf, the object being to secure great sensitiveness and a negligible capacity. The quartz fibre was charged by connecting it with one pole of a battery of fifty Daniells. The disks having been earthed while several centimetres apart, then insulated and slowly brought to within ½ millimetre of each other, there was a deflection of the

quartz fibre amounting to 2·5 divisions of the scale used, and indicating that the zinc was negative to the copper, that is to say, the direction of the charge is opposite under these conditions to what it would be under the ordinary conditions of Volta's experiment. On withdrawing the plates to their original distance apart the quartz fibre returns to zero, but if they are earthed for a moment or two while close together and then separated the quartz fibre is deflected in the opposite direction, showing that the zinc is now positive to the copper. The deflection is in this case much larger, owing to the greater capacity of the plates when close together.

The Author describes an apparatus analogous to an influence machine, in which the rotation of two semi-disks of zinc and copper in front of armatures of copper and zinc generates a small but measurable current.

As a necessary consequence of Volta's theory it follows that two metals connected by a conductor, being at different potentials, must attract each other. Lord Kelvin has recently pointed out that the experimental verification of this would be difficult if not impossible. The Author has succeeded in the following manner: A fine quartz fibre, silvered, is suspended so that its lower extremity almost touches a polished plate of zinc 1 centimetre square, fixed by the side of it in a nearly vertical plane. A microscope is so placed that the end of the quartz fibre and its reflection in the zinc plate can be simultaneously observed. The quartz fibre and the zinc plate being connected with each other and with the earth, the zinc plate is brought gradually nearer by a screw. When the distance between them is about 0·2 millimetre the silvered quartz fibre is suddenly attracted by the zinc plate. Aluminium attracts more than zinc, and gold less. A gilded fibre is not attracted by a gold plate, and only slightly by one of silver. The difference of potential between the metals may be balanced by a potentiometer, in which case there is no attraction till the compensating current is cut off. The Author has used this method of measuring the contact potential of a number of metals.

G. J. B.

The Austrian Magazine Rifle M 95. HOFFMANN.

(Mittheilungen über Gegenstände des Artillerie- und Genie-Wesens, 1899, p. 44.)

The new rifles have the same calibre and fire the same ammunition as the M 90 patterns, but, chiefly owing to the employment of a stronger steel, are considerably lighter. The infantry rifle is sighted up to 2,600 yards, the short infantry rifle (*Stutzen*) and the carbine up to only 2,400 yards. In the following Table the new weapons are compared with the old :—

Weapon.	Weight.	Length.	Work done by Recoil.	Initial Velocity.	Velocity of Recoil.
Magazine rifle, M 90	With bayonet, 4·865 kilograms (10·72 lbs.). Without bayonet, 4·490 kilograms.	With bayonet, 1·525 metre (5·00 feet). Without bayonet, 1·281 metre.	1·11 metre-kilogram (8·02 foot-lbs.).	620 metres (2,034 feet)	2·23 metres (7·31 feet)
Magazine carbine, M 90	3·290 kilograms.	1·005 metre.	1·23 metre-kilogram.	580 metres	2·70 metres
Magazine rifle, M 95	With bayonet, 3·935 kilograms. Without bayonet, 3·650 kilograms.	With bayonet, 1·518 metre. Without bayonet, 1·272 metre.	1·83 metre-kilogram.	620 metres	2·68 metres
Magazine short infantry rifle (Stutzen), M 95	With bayonet, 3·415 kilograms. Without bayonet, 3·130 kilograms.	With bayonet, 1·251 metre. Without bayonet, 1·005 metre.	1·86 metre-kilogram.	580 metres	2·92 metres
Magazine carbine, M 95	3·060 kilograms.	1·005 metre.	1·39 metre-kilogram.	580 metres	2·99 metres

W. B.

Fortifications. Baron Von Leithner.

(Mittheilungen über Gegenstände des Artillerie- und Genie-Wesens, 1899, p. 1.)

The Author discusses the arrangement, design and armament of fortified points in a chain or girdle of works protecting an extended position. The defence of each point requires a primary battery of heavy guns to keep the enemy at a distance, and light secondary batteries of quick-firing and machine guns to secure the work and the areas intervening between the fortified position and the neighbouring positions in the chain, against assault.

The armament, equipment and relative position of the two types of battery depend first upon the character of the ground, which determines the distance apart of the fortified points. Upon

this distance depends the weight of the guns mounted in the secondary batteries, which again affects the design and requirement of the primary works.

The Author places the theoretical distance of the primary battery behind the secondary batteries at between 300 and 500 metres (328 and 546 yards), and that between the several fortified points at 3,000 to 4,000 metres.

The Paper is illustrated. W. B.

Permanent Fortifications: their Use and Design.

Baron Von Leithner.

(Mittheilungen über Gegenstände des Artillerie- und Genie-Wesens, 1899 p. 679.)

The Author discusses at some length the reasons governing the erection of fortifications and their extent and character. Apart from the defence of a capital or other place of political importance, protective works are needed at the chief points on lines of communication and at depôts for the storage of war material.

Dealing with the general arrangement of a girdle of forts, the Author deprecates extending them too far, as the cost is increased and larger garrisons needed. Inside the main line of forts it is necessary to have a continuous circle of works to protect the central position from storm, and on various grounds it is contended that the area within these secondary works should not be restricted. A radius of from 6 to 7 kilometres (3·7 to 4·4 miles) is suggested for the main forts forming the girdle, and 2 to 3 kilometres for the continuous secondary defences. The design of the main and secondary defences, their armament and the organization and number of the garrisons required, is considered. Also how far and under what conditions it may be advisable to leave the construction of the whole or part of the defences, until there is a probability of attack.

The Paper is illustrated by three Plates, including a detail example of the fortifications of an imaginary town.

W. B.

Engineering Education in the United States.[1]

Marcel Delmas.

(Mémoires de la Société des Ingénieurs Civils de France, November, 1899, pp. 660–667.)

Having visited in 1899 Pennsylvania University in Philadelphia, Columbia College in New York, and Cornell University at Ithaca, the Author describes more particularly the features of the last,

[1] Minutes of Proceedings Inst. C.E., 1894, vol. cxvii., p. 499.

which has more than two thousand students, almost all outside, who enter generally at the age of seventeen or eighteen, after a preliminary examination of no great difficulty, and continue their studies for four years. Idlers are weeded out by quarterly examinations of a searching nature. The advantages here met with are contrasted with the technical education received by French students at the University of Paris, the Sorbonne, the École Polytechnique, the École Centrale, and the Conservatoire des Arts et Métiers. On leaving at the age of twenty-two, a Cornell student has become a practical engineer, able himself to work in the joinery, smithy, machine shop, and foundry; having himself had a hand in constructing, testing, and working all kinds of machines, hydraulic, electric, and others; and capable already of managing difficult works in the wildest localities, as well as of dealing with the theory and the details of novel contrivances. He is thus spared the necessity of confining himself for a further term of years to the position of an assistant in some special branch of the profession; and has not been called upon to give up part of his time to military service. Particulars are added of the low expenses attending the college career, and of the students' mode of life, recreations, and holiday doings. The highly advantageous financial position of the university is set forth at some length, together with an account of the original outlay upon the building, and upon the equipment of its several departments, the total amounting to little less than the cost of the Palace of Versailles. Mention is made of Lehigh University, founded on the same plan as Cornell; and of the Massachusetts Institute of Technology in Boston, which resembles more the Polytechnic Schools in Zurich and Berlin. The laboratory of Columbia College contains two full-size locomotives, with their wheels carried on dead rollers, on which they can be driven up to full speed.

A. B.

Variations of Apparent Horizon. F. A. FOREL.

(Comptes Rendus, vol. cxxix., July 31, 1899, pp. 272–274.)

The Author has recently been engaged in the study of aerial refractions and mirages on the surface of the Lake of Geneva, and in the course of his work has been able to make some observations on the displacement of the apparent horizon. The work was carried out at Morges, in a laboratory on the border of the lake, where he could command a length of horizon of about 16 kilometres. Observations were made with a telescope mounted on a stone pier of such height that the horizon was 5 or 6 kilometres distant, and the level was determined by sights, both direct and with an artificial horizon. The angular differences between the true and apparent horizon varied from $+501''$ and $-272''$, showing a total variation of $773''$, or $13'$ of arc.

The factors causing this difference are: temperatures of the air and water, humidity and agitation of the air, direction and quality of wind, and variations of atmospheric pressure.

Tables are given of the various values observed, from a discussion of which the following general rules are deduced:—

1. The possible error in the position of the true horizon as deduced from observations of the apparent horizon is greater when the air is calm than when it is agitated.

2. It is greater when the air is warmer than the water.

3. Since the observations are more uncertain when the air is calm and warmer than the water, morning observations are better than those made in the afternoon.

C. P. B.

Hysteresis at Low Temperatures. A. H. Ford.

(Electrical World and Engineer, vol. xxxiv., August 5, 1899, p. 195.)

A sample of transformer iron was tested for hysteresis with a Ewing hysteresis tester at the ordinary temperature of the room. It was then plunged into a beaker of liquid air, allowed to cool, quickly removed, and tested while cold. Finally, another test was taken when the iron had attained the ordinary temperature. Four samples of the same kind of iron were examined in this way, and the mean results, giving the hysteresis loss in ergs per cycle per cubic centimetre, at the density of one gauss, were as follows:—

		Increase per Cent.
Initial	0·00124	
Cold	0·00159	28
After warming	0·00139	12

Some other samples of the same kind of iron showed the following effect of heat treatment:—

		Hysteresis Loss.
Annealed from	853° C.	0·0014
Quenched in water from	225° C.	0·00125
Quenched in water from	400° C.	0·00145
Quenched in water from	804° C.	0·00150

A. H.

High-Temperatures by means of Aluminium. H. Goldschmidt.

(Zeitschr. Elektrochem., vol. vi., July 20, 1899, pp. 53–57.)

In this paper, read before the annual meeting of the German Electrochemical Society, the Author reports upon the technical utilisation of his process for obtaining high temperatures by means of powdered aluminium. The details of this process were

described in a previous paper before the Society. The applications of the method are three :—

1. The production of metals and alloys. Manganese, chromium, various alloys of these two metals, ferro-titanium and ferro-boron are being produced at Essen by a company called the "Chemische Thermo-Industrie," and the industrial utilisation of the process is about to occur in France.

2. The production of artificial corundum. This by-product of the reduction of metallic oxides by powdered aluminium is finding a ready sale for various purposes.

3. The production of heat for metal-working operations. The method is being used for hardening, for hard soldering, for welding, and other operations. The localisation of the heat is an important characteristic of the process. Its use for rail-bonding by welding on electric tram-lines, has been successfully initiated at Essen.

Defective parts in steel-castings can be made good by this method.

J. B. C. K.

Lightning and Lightning Arresters. H. E. Raymond.

(American Electrician, vol. xi., June, 1899, pp. 214–215 and 262–263.)

Leyden jar experiments seem to show that (1) the lower the voltage the smaller the effect of resistance upon the discharge; (2) the greater the capacity the less is the discharge affected by resistance; (3) the shorter the resistance for a given cross section the less its influence; (4) the discharge will be affected by any reactance to quite a considerable extent.

In the action of arresters on the line we note, first, that the discharge is opposed by considerable length of resistance, and but little by amount of resistance in ohms in shorter lengths; second, that the length of gap determines the striking-point of the arrester; third, that the inductance of the line introduces a favourable factor; fourth, that the capacity of the discharges affects the striking-point, in that for a given distance the greater the capacity the lower the striking tension; fifth, that reactance coils offer but little impedance to lightning discharges, and a considerable opposition to Leyden jar sparks; sixth, that the voltage of line discharge is much less than that of the Leyden jar, with a long gap in series with its circuit.

Considering the line as a condenser alternately charged by the atmospheric disturbances and discharging to earth at certain conditions of electrostatic unbalancing or dielectric strain, there are the following differences between this condenser and its action and the Leyden condensers and their action: the line is presumably of higher capacity, and certainly of greater self-induction; the lightning discharges are of much lower frequency, as is shown

by the slight effect of a reactance coil upon them. These points explain the fact that an arrester with a short gap and a moderate resistance in series will take a line discharge in preference to one without resistance and with a longer gap.

W. G. R.

Fuse-Wires for Air-Lines. J. MATTAUSCH.

(Zeitschrift Elektrotech Wien, vol. xvii., 1899, pp. 159–160.)

In localities where danger is likely to occur to aerial lines, owing to stray currents from other circuits or to lightning, it is proposed to introduce fuses into every span of wire. The fuses are arranged so that the line-wires exert no strain upon the fuse-wire; and when a fuse "blows," the line-wires are still upheld. To get this result an insulating shackle is introduced into each span to take the strain, and fuse-wire is used to establish electrical connection between the ends of the shackle. Various modifications are described.

R. A.

Concentric Wiring. M. O'GORMAN.

(Electrical World and Engineer, vol. xxxiv., August 12, 1899, pp. 228–231.)

A defence of this system is given—it does not affect telegraphs or the ship's compass. Leakage current, shocks, or fires are impossible; the quantity of copper and rubber in cables is diminished; lamps can be screwed into the same sockets as fittings if the latter break down. Concentric flexibles are smooth externally, and being at zero potential attract no dust. Switchboards are waterproof and cheap because single pole. A special method of testing cables is given.

E. H. C.-H.

Electrical Machinery on Board Ship. A. SIEMENS.

(Electrician, vol. xliii., September 29, 1899, p. 815.)

The chief advantage of electric power on shipboard is the absence of clumsy and leaky pipes. The difficulty is the variations in the loads on auxiliary machinery. The strain on a winch often stops it. In such cases, shunt-wound motors driving through friction clutches are used, or else series-wound motors with a special cut-out arranged to break the main circuit on occasion, and only allow a certain current to flow through a by-pass circuit. The Author mentions an electric steering gear and rudder indicator as an example of the first method.

E. H. C.-H.

Thawing Water-Pipes with Electricity.

(Canadian Electrician News, vol. ix., 1899, pp. 57–58.)

Frozen water service pipes are thawed by means of alternating currents passed through the pipes themselves. A pressure of 20 volts to 50 volts is used, obtained from a portable transformer connected with the street mains; a current of 200 amperes to 400 amperes is passed through the frozen pipe until the water flows freely, which usually takes place in a few minutes. Details of actual cases are given.

A. H. A.

Simple Steam-Engine with Remarkable Economy.

(American Electrician, vol. xi., 1899, p. 208.)

The steam engine designed by Elihu Thompson for steam automobile work has four cylinders each $2\frac{1}{2}$ inches diameter and 3 inches stroke, all single acting and worked single expansion, the output of the four being about 5 H.P. The economy obtained with this small engine reached $20\frac{1}{2}$ lbs. of water per H.P.-hour, the steam pressure being between 160 and 200 lbs. with a considerable degree of superheating, the engine at times being worked with the steam-pipe red-hot. The steam is admitted to the cylinder by a simple poppet-valve, and expands until the piston uncovers the exhaust ports. The conditions are such that there is no retraversing of any of the passages by the steam. The steam is always moving in one direction, so that there are no inter-actions to cause waste of energy.

A. S.

Over-Compounding Dynamos. E. K. Scott.

(Electrical Review, vol. xlv., September 15, 1899, pp. 428–429.)

The Author describes a method of compensating for the curvature of the B—H curve by shunting the series coils with iron wire; as the load increases the resistance of the iron increases with rise of temperature more rapidly than that of the copper coils, thereby shunting a smaller proportion of the total current. It is remarked that over-compounding, by increasing the magnetic flux, tends to reduce sparking at the brushes. The common practice of specifying that dynamos for electricity works shall be designed for 460 volts for lightning, but shall be able to work at 550 volts for traction, is criticised on the score that the weak field in the former case conduces to sparking and involves increased first cost.

A. H. A.

The Feeder System at Boston, U.S.A.

(Railway World, vol. viii., July, 1899, pp. 237–244.)

The mileage operated is over 300 miles of single track, and the cables used comprise 510 miles of feeders and 70 miles of insulated return wires. The sections of copper were calculated from the following formula:—

$$S = \frac{1 \cdot 5\, P A M G^2}{V^2 (G-1)}$$

where—

S = cross section of feeder in circular mils.
P = power delivered to cars in watts, nominal.
A = specific resistance of copper per mile-mil.
M = distance to centre of load, miles.
V = pressure at power station in volts.
$1 \cdot 5$ = a constant representing the ratio between total drop and feeder drop.
G = economical constant which may have any value between 1 and 2 and is determined by one of the following formulas:—

For overhead lines—

$$G = 1 + \sqrt{\frac{2 \cdot 25\, M^2 A (C D + E_o F_o)}{2 \cdot 25\, M^2 A (C D + E_o F_o) + V^2 (H I 8760 + J K)}} \quad \text{or}$$

For underground lines—

$$G = 1 + \sqrt{\frac{2 \cdot 25\, M^2 A (C D + E_u F_u)}{2 \cdot 25\, M^2 A (C D + E_u F_u) + V^2 (H I 8760 + J K)}} \quad \text{or}$$

where—

C = cost of copper in dollars per mile-mil (copper only, and does not include cost of insulation and installing).
D = interest and depreciation on above amount.
E_o = cost of insulating and installing copper overhead per mile-mil.
E_u = cost of insulating and installing copper underground per mile-mil.
F_o = interest and depreciation on above amount for overhead lines.
F_u = interest and depreciation on above amount for underground lines.
H = time factor of energy lost in feeder.
I = cost of producing this energy per watt-hour.
J = cost of generating plant per watt installed.
K = interest and depreciation on plant.

The average insulation resistance of the underground cable ranges from 200 megohms to 1,500 megohms per mile.

E. H. C.-H.

Plymouth Electricity Works.

(Electrical Engineer, vol. xxiv., July 28, 1889, pp. 102–110, and August 4, 1899, pp. 146–149.)

These articles contain a full illustrated description of the Plymouth combined lighting and traction works. The lighting plant is 2,000 volts alternating and the traction plant 500 volts continuous current. One engine carries a dynamo and an alternator on the same shaft in order to deal economically with light loads. The coal arrangements are very complete, and the whole cargo of a 600-ton ship can be discharged in two days. Lancashire boilers without cross-tubes are used, worked at 130 lb. pressure, but constructed for 160 lb. to avoid reduction in working pressure as the boilers age. Instead of being individually lagged, a non-conducting floor has been formed over the battery of boilers. The motors of the electric 3-throw pumps are arranged with two totally distinct circuits to their armatures, so that they can be economically run at 730 revolutions per minute when the two circuits are in parallel, or at 365 revolutions per minute when in series. The feed and steam pipe arrangements have received particular attention. A ring steam main has been avoided.

E. H. C.-H.

Electric-Traction Statistics as Data for Design. A. Hecker.

(Electrotechn. Ztschr., vol. xx., August 17, 1899, pp. 590–592.)

The Author, after carefully investigating available statistics, finds that if abnormal cases be excepted, there are definite relations connecting the number of inhabitants with the gross receipts and the number of car-miles run. These relations may be expressed by the following formulas;—

$$y_1 = 2 \cdot 5 \times 1 \cdot 12^{\frac{x_1}{4} - 1}$$

where y_1 denotes the receipts per head per year, in shillings, and x_1 the number of inhabitants divided by 10,000. Further—

$$y_2 = 10 \times 1 \cdot 08^{\frac{x_1}{4} - 1}$$

y_2 denoting the number of car-miles per year per inhabitant.

A. H.

Rail-Bonding. R. D. Appleton.

(Railway World, vol. viii., July, 1899, pp. 269–270.)

Paper read before the Railway and Electrical Association of Virginia, U.S.A.

Bonds of solid copper become loose owing to expansion. Flexible bonds break off. Electric welding decarbonises the ends of the rails and results in two thumps per joint instead of the usual one. Cast welds are good mechanically, but their resistance is high, and gets higher with time. The ideal bond must absolutely prevent corrosion of contact surfaces by excluding water in spite of all variations of temperature. It must be able to give and take as much as an eighth of an inch per joint again and again without breaking or crystallising. It should be capable of carrying as much current as the rail itself. The Author has in three years' experience found these qualities in the plastic bond.

E. H. C.-H.

Electric Rail-Welding.

(Electrical World and Engineer, vol. xxxiv., August 12, 1899, pp. 234-235.)

This is a short description of the electric rail-welding plant of the Lorain Steel Company, Ohio, as employed in making 7,500 rail joints in the Buffalo street railway system. The trolley wire current is transformed by a rotary converter carried on a car, into single-phase current of 300 volts, and then down to 5 or 7 volts by a static transformer of one secondary turn giving up to 25,000 amperes. The joint is made by means of fishplates welded on to either side of the web under heavy pressure. Each joint takes fifteen minutes to complete.

L. B.

Brake Shoes.

(Street Railway Review, vol. ix., July, 1899, pp. 447–480.)

This paper gives an account of patents on brake shoes for the last thirty years, of tests prior to 1895, and a summary of the most recent experiments. A table showing the mean coefficients of friction is given, having been prepared from the data published in the Master Car Builders' Proceedings, from the Reports of Tests made for the Sargent Company, Chicago, and from the Reports of Tests by Goss of Purdue University. The tests were made at initial speeds of 65 miles, 40 miles and 30 miles per hour respectively; and two diagrams are given showing the mean co-

efficient of friction, and the distance run before stopping on the assumption that each shoe has to absorb the energy of a mass of 12,000 lbs. As a rule, the coefficient of friction is less at the high speeds; the total variation over the experiments recorded, being from 11 per cent. to 39 per cent. The effects of the various brake shoes on a chilled wheel and on a steel-tired wheel are recorded.

A. S.

W. R. Smith's Overhead-Conduit System.

(Railway World, vol. viii., July, 1899, pp. 266–268.)

The conduit is a small tube of papier maché, suspended horizontally 22 feet above the street by $\frac{1}{16}$ inch steel wires hung from a 1 inch wire rope supported on poles 100 yards apart. Current is taken from two copper rails supported on insulators within the conduit. A small truck with four flanged wheels runs on the rails within the conduit, being kept in contact by a roller and spring. This truck is drawn along by conductor cords, which are reeved over a pair of tackle falls on the car to pay out and in at a uniform tension, to allow for the lateral movement of flangeless wheeled vehicles on ordinary roads. At points a short length of the conduit before the branch is hinged and is swung from one line to the other by the motor man pressing a button in the circuit of one of two electromagnets. The claims for this system are: (1) It costs 48 per cent. less than the trolley system to convert an existing tramway from horse haulage to electric traction. (2) It costs 10 per cent. less than the trolley system to lay a new line. (3) Freedom from all electrolysis. (4) There is no wear upon the supporting wires, and no lateral strain upon the supporting pillars. (5) Tramway rails may be dispensed with where the traffic is light or the rails inconvenient. (6) The points and crossings of the conduit are on one level.

E. H. C.-H.

Combined Electric and Petrol Motor Car. É. Hospitalier.

(Ind. Élect., vol. viii., July, 25, 1899, pp. 316–319.)

The Pieper Company have brought out a car which is normally propelled solely by an oil engine, but on hilly ground is helped by an electric motor. The oil-engine works at a constant rate, and when the vehicle does not absorb all the engine's power the excess drives the motor as a dynamo and charges the accumulators. As the accumulators only have to supply power occasionally, they are kept fully charged, and can therefore (as was clearly shown at the French Automobile Club cell trials) safely give rates of dis-

charge which would seriously damage them if the cells were only partially charged. The engine having always to work at constant speed and load, a simple carburetter is used, adjusted once for all. The engine is direct coupled to the dynamo-motor, which is shunt wound, and is used to start up the engine. The rate of charging can be adjusted by field-regulation. Changes of speed are effected mechanically. The engine gives 2,500 watts, and the motor about 1,800 watts, so that on hills nearly 5,000 watts can be obtained. The battery of 40 cells weighs 125 kilograms complete, and can give up to 20 watts per kilogram of total weight. Backward motion is obtained by shutting off the carburetted air from the engine and reversing the current in the armature of the motor. The three-passenger vehicle complete, without live weight, weighs 600 kilograms and runs up to 30 kilometres per hour. It will take 12 per cent. grades at 12 kilometres per hour. The Author predicts that the "petro-accumobile" will be the cab of the future.

E. H. C.-H.

Investigation of the Microphone. J. Cauro.

(*Éclairage Électrique*, 1899, p. 295 *et seq.*)

A study of the current variations in primary and secondary circuits of the electromotive force on open and closed circuit, of the energy spent in a telephone, and of the magnitude of the movements of the diaphragm. The instruments selected are described. Alternating potentials were measured by a Curie electrometer (with flat mirror and giving virtual images) used only as an electroscope. Alternate currents were taken by a modified electro-dynamometer by Giltay-Bellati with soft iron needle, used only as a zero instrument. A spiral-strip oscillograph, which, however, required standardizing with an electrometer for each frequency, was used, and the movements of the strip in a strong field noted with a microscope. A telephonic relay having only the self-induction capacity and resistance of a short straight wire was made on the basis of the oscillograph. There is practically no limit to the number of such instruments which might be placed on one line without destroying distinctness.

The source of sound was a pipe whose lip was vibrated electrically to avoid any movement of translation of the air. Sound intensity was measured by observing with a microscope the movements of a rubber membrane, and incidentally it is proved that the movements of the membrane are due to the air only. The displacements of microphone and receiver diaphragms were measured by fixing a glass disk to the membranes and utilizing Newton's rings, the displacements being suitably slowed down by Lippmann's stroboscope, which is explained and illustrated.

Speech consists of a series of musical vowels separated by

stoppages (the consonants), which give rise to extra currents more easily audible than the pure musical notes. All measurements were made after the musical note had been established. When the electrometer method was used for current measurement a resistance without self-induction or capacity was necessary, and the potential difference at the ends of a known resistance gave the effective current. The Table of results cannot be abstracted, but the following is an example: With a distance of the pipe from the microphone of 175 millimetres through 20 kilometres of cable with the loudest note which did not produce cracking sounds, the mean receiver voltage was 2·38, the effective voltage was 2·46, the microphone terminal volts were 1·35 mean and 1·28 effective; the current through the microphone at rest was 0·078 ampere, the mean current variation was 0·03, and the effective current variation was 0·28 of the microphone current when at rest. It was found that the effective variable current is independent of the pitch, is proportional to the amplitude of vibration of the sound, and is about a quarter of the steady current, which continues unchanged during transmission. The effective electromotive force on open circuit varies as the amplitude of sound and inversely as the pitch. Sound is still audible with $\frac{1}{1000000}$ ampere in the secondary, and this current does not appear to vary with the pitch (ω). It will be seen that various notes are not affected differently by the telephone, and therefore that timbre should not be lost in transmission. This depends on the importance of the self-induction (L) of the usual apparatus, whose apparent resistance is $\sqrt{R^2+L^2\omega^2}$, namely, at 600 periods R^2 is about 10^6, whereas $L^2\omega^2$ is about 50×10^6. On a long distance line like Paris-Marseilles the apparent self-induction of both line and insulation is a few hundredths of a henry, so that R^2 is of the order 10^6 and $L^2\omega^2$ is 2×10^3. Hence, as far as distortion of sound is concerned, the line acts as a resistance which is not as important as the apparent resistance of the apparatus. The latter depends mainly on the pitch and the self-induction.

M. O'G.

Alternating-Current Theory. C. P. Steinmetz.

(American Institution of Electrical Engineers, Transactions, 1899, p. 289 *et seq.*)

In the first part of the Paper the Author deals with the representation of the power in an inductive circuit by means of a vector graphically, or by means of a complex number analytically. The electromotive force E and current I in a circuit may be represented by two vectors in an Argand diagram corresponding to the complex numbers $E = e_x + ie_y$ and $I = i_x + i\,i_y$ respectively (where $i^2 = -1$). If we take the product EI of the two vectors, we find that this does not correspond to the power. The power vector is, in fact, a vector whose frequency is double that of E or I, and hence it

cannot be represented in the same diagram with E and I. This leads us to consider the product E I when the phase angle is doubled. Forming this product, and remembering that now i^2 must be put $= +1$, since a rotation of π radians for E or I corresponds to a rotation of 2π for the product, we find $[E\,I] = (e_x i_x + e_y i_y) + i\,(e_y i_x - e_x i_y)$, where the square brackets are used to indicate a doubling of the frequency. The real component of $[E\,I]$ gives the true power in the circuit, and the imaginary component the wattless volt-amperes. By squaring and adding the two components, the square of the total volt-amperes or apparent watts in the circuit is obtained. The author points out that $[E\,I] = -[I\,E]$, so that the law of commutation ceases to hold in this case. The method of representing power just explained is applied by the Author to the problem of two polyphase induction motors coupled mechanically and electrically, the secondary of the first motor being closed by the primary of the second motor. In the second part of the Paper, the Author considers the symbolic representation of electromotive force and current waves of irregular shape. In many cases, instead of considering such waves, we may use equivalent sine wave. In other cases, however, especially in circuits containing capacity or periodically varying resistance or reactance (*e.g.*, alternating arcs, synchronous induction motors, over-saturated magnetic circuits, &c.), the use of an equivalent sine wave is not permissible. The Author proposes to use the following symbolism in such cases. The general alternating wave of electromotive force, viz., $E = E_1 \sin(pt \quad a_1) + E_3 \sin(3pt - a_3) + \ldots$ may be written in the form $E = \sum_{n=1}^{n=\infty}{}^{2n-1}(e_n + i_n e'_n)$, where $i_n{}^2 = -1$, the suffix n merely denoting that the components of the various terms represent different frequencies, and thus cannot be combined. If now the impedance of the fundamental harmonic be represented by $z_1 = r + i\,(x_m + x_o + x_c)$, where x_m stands for that part of the reactance which is proportional to the frequency (inductance, &c.); x_o for the part independent of the frequency (mutual induction, synchronous motion, &c.); and x_c for the part which varies inversely as the frequency (capacity, &c.), then the impedance for the nth harmonic is $z_n = r + i_n\left(n\,x_m + x_o + \frac{x_c}{n}\right)$, and the current may be represented by $\sum_{n=1}^{n=\infty}{}^{2n-1}\dfrac{e_n + i_n e'_n}{r + i_n\left(n\,x_m + x_o + \frac{x_c}{n}\right)}$.
The use of this symbolism is illustrated by numerical examples.

In the discussion, L. Bell called attention to the imperfection of the ordinary sine wave calculations when applied to long lines having combined inductance and capacity. D. C. Jackson contributed the following note on a method of treating the power vector, which he considers simpler than Steinmetz's method. Let $\operatorname{cis}\theta = \cos\theta + i\sin\theta$, so that $\operatorname{cis}\theta$ represents the operation of turning a vector through an angle θ. Writing $E = \bar{E}\operatorname{cis}\theta$, and

$I = I \operatorname{cis}(\theta - \phi)$, and denoting the power vector by P, we have $P = E I = E I \operatorname{cis}(2\theta - \phi) = (E I \cos\phi - i E I \sin\phi) \operatorname{cis} 2\theta$, and it is clearly seen that P has twice the frequency of I and E. Moreover, the ordinary commutative law is valid in this case.

A. H.

Hysteresis Loss in Transformers. W. PEUKERT.

(Elektrotechnische Zeitschrift, September 21, 1899, p. 674.)

An inquiry into the limitations of the Steinmetz formula for arriving at the hysteresis loss of all alternate current transformers, in which—

$$W = n \,.\, B_{max}^{1\cdot 6}\, p \,.\, V \,.\, 10^{-7},$$

W representing the watts lost,
n a constant depending on the quality of iron,
B the magnetic lines per square centimetre,
p the periodicity per second,
V the total volume of the iron in cubic centimetres.

A Table is given showing that whilst the constant n might be 0·002 for a given sample of iron at the values for B usually employed in transformers' work, the constant may increase as much as 70 per cent. or 80 per cent. when carried to higher values thus:—

$B_{max.}$	n	$B_{max.}$	n
2660	0·00222	12250	0·00256
4698	0·00221	14124	0 00301
6756	0·00224	15838	0·00372
10197	0·00246	17243	0·00383

The results of a series of tests on a transformer are tabulated for the various periodicities, viz., 24, 30, 33·3, 37·3, 41·3, 46·67, 50·67, 54·67, and the following maximum values of B, viz., 2,187, 3,522, 4,173, 5,192, 5,843, and 6,260. The Author gives the following formula for arriving at a suitable B for different periodicities, &c.:—

$$B_{max} = \frac{0\cdot 9\, E \,.\, 10^8}{4 \,.\, p \,.\, m \,.\, q}$$

Where E is the voltage,
p the periodicity,
m the number of turns of coil,
and q the cross section of the iron in square centimetres.

E. K. S.

Gas Reactions in Chemical Kinetics. M. BODENSTEIN.

(Zeitschrift Phys. Chem., May–October, 1899, p. 147 *et seq.*)

(1) Gas reactions have the advantage over those in the liquid state that they can be extended over wide temperature intervals (200°–300°). The approximate uniformity of the temperature coefficient of the latter arises from the fact that all have been investigated within about the same range of temperature. By theory a falling off at high temperatures of the rate of increase of reaction velocity is to be expected, as is in fact found in the case of the following gases. "Pseudo equilibrium" has been put forward experimentally by Pélabon and Hélier, and theoretically by Duhem, and is now investigated by the Author.

(2) The theory is tested with HI between 283° and 508°. The heat production (Wärme-tönung) q, calculated from the coefficients of equilibrium, is found to vary considerably with the temperature, and is of the form $A+BT+CT^2$, and therefore K, k_1 and k_2, each of the form—

$$\log K = -\frac{RT}{A} + \frac{R}{B} \, ln \, T + \frac{C}{R} T + \text{const.}$$

The relation $K = \frac{k_1}{k_2}$ is found to hold between 356° and 508° within the somewhat wide limits of experimental error; the differences below 356° (up to 35 per cent.) may be due to the failure of iodine vapour to obey the laws of an ideal gas. The value of q extrapolated to 20° agrees but poorly with that observed in the calorimeter. The increase of velocity of decomposition for 10° rise of temperature between 300° and 500° is somewhat less (1·9 to 1·5 times) than that observed for liquid reactions at ordinary temperatures.

(3) The combination of hydrogen and sulphur is found to be practically complete at 300°–500°, and the inverse reaction only reached a few tenths per cent. after long heating. Pélabon's "pseudo equilibria" are therefore only erroneous observations due to shortness of time. The velocity of combination is determined at 356° for varying H_2 concentration with constant vapour pressure of sulphur, and also for varying concentrations of sulphur, and found to be proportional to the former and nearly to the square root of the latter, the formula $\frac{dx}{dt} = k(a-x)(b-x)^{\frac{1}{2}}$, where a and b are the original concentrations of hydrogen and sulphur, agreeing best with the results. This the Author explains by supposing that the reaction takes place in three stages—

$$S_8 = 4S_2,$$
$$S_2 = 2S,$$
$$H_2 + S = H_2S,$$

of which the first is negligibly slow, the second (almost) negligibly fast, and the third is that of which the velocity is measured. The concentration of S must then be proportional to the square root of that of S_2, and the latter will be practically proportional to that of S_8. The increase of velocity for every 10° rise of temperature is comparable (1·4 to 1·8) with that observed in liquid reactions.

(4) Hydrogen selenide decomposes, and likewise is formed much faster, when the walls of the containing vessel are coated with selenium, and the proportionality between the velocity and the quotient, surface/volume, indicates that the reaction takes place entirely on the surface. The equilibrium attained is the same for both formation and decomposition when sufficient time is allowed, thus disproving Pélabon's "pseudo equilibria." Other criticisms of Pélabon's Paper are also given.

(5) The combination of H_2 and O_2 between 482° and 689° is studied by passing the gases, mixed in different proportions, through clean porcelain tubes, and measuring the diminution in volume. The time spent by each portion in the heated tube is calculated and the velocity of combination determined. The reaction is found to take place exclusively on the walls of the tube, and is shown by the satisfactory constancy of the calculated coefficient to be trimolecular, in accordance with the equation—

$$2H_2+O_2=2H_2O.$$

The velocity varies with the tube used, and its temperature coefficient is somewhat uncertain. The formula—

$$\log k = -\frac{16298}{T} - 48\cdot455 \log T + 163$$

is given. At the highest temperatures the transition to an explosive reaction was clearly shown, in accordance with van't Hoff's explanation, the velocity rising, owing to evolution of heat, more rapidly than the walls of the tube could equalize. Hélier's "pseudo equilibrium" was not observed.

(6) Various forms of baths and thermostats for constant high temperatures are described, applicable from 100° to 700°.

(7) Summary of results.

B. B. T.

Dissociation of Gases. R. Wegscheider.

(Akad. Wiss. Wien., Sitzungsber, 1899, p. 69.)

Under constant external pressure and at a uniform temperature the proportionate number of gram-molecules dissociated is, when there is an infinite dilution with one of the products of dissociation,

the square of what it is when there is no such dilution; that is, when the products of dissociation are two in number. For intermediate conditions the proportion dissociated is intermediate; and no amount of dilution with one of the products will altogether prevent dissociation from taking place. If the dissociation-reaction be that n_0 gram-molecules break up into n_1 n_2, ... etc., gram-molecules, there are three cases; (1) $n_0 - (n_2 + n_3 + \text{etc.}) < 0$, where n_1, the missing n, is that corresponding to the product of which an excess is added: in this case the dissociation, at infinite dilution with the product of dissociation, is complete; (2) $n_0 - (n_2 + \text{etc.}) = 0$, in which case the proportion between the dissociated and undissociated at infinite dilution with one product is—

$$\sqrt[n_0]{\left\{\left(\frac{n_1}{n_0}\right)^{n_1} \cdot \frac{a^{n_1} + n_2 + \text{etc.}}{\left(1 + \frac{n_1}{n_0}a\right)^{n_1}\left(1 - a\right)^{n_0}}\right\}}$$

where a is the proportion dissociated when there is no dilution; and (3) $n_0 - (n_2 + \text{etc.}) > 0$, in which case an excess of a product completely checks dissociation. Examples of these three cases: (1) [not given: *qy.* ammonia gas diluted with nitrogen?]; (2) carbonic acid diluted with oxygen: $2\,CO_2 = O_2 + 2\,CO$; $n_0 = 2$, $n_2 = 2$; $n_0 - n_2 = 0$; the dissociation has a definite value at all dilutions with oxygen; hence no excess of oxygen will enable carbonic oxide to become thoroughly burned into carbonic acid; and where the proportions dissociated without dilution with oxygen were 0·01, 0·1, 0·3, 0·5, 0·7, 0·9, respectively, the corresponding dissociations at infinite dilutions with oxygen would be 0·0007, 0·024, 0·134, 0·309, 0·543, and 0·834, so that the restraining effect of the addition of oxygen rapidly falls off as the original tendency to dissociation increases; (3) carbonic acid diluted with carbonic oxide: $2\,CO_2 = 2\,CO + O_2$: $n_0 = 2, n_2 = 1$; $n_0 - n_2 > 0$; a considerable excess of carbonic oxide will completely prevent dissociation. Under constant volume on the other hand, an excess of one of the products will restrain, and an infinite excess will completely prevent dissociation. When a reaction in a dilute solution is associated with a change in the osmotic pressure, there is on further dilution a change in the equilibrium such as tends to increase the osmotic pressure, and thus acts in a sense opposed to the dilution. The presence of phosphorus trichloride does not completely prevent the dissociation of phosphorus pentachloride: some 3 per cent. to 10 per cent. was dissociated in Wurtz's experiments.

A. D.

Cost of Calcium Carbide. F. LIEBETANZ.

(Zeitschr. Elektrochem., August 10, 1899, p. 117.)

This is a report of an address delivered at the second Buda-Pesth Acetylene Congress in May, 1899. The Author seeks to answer the question as to the relative economy of gas-, water- and steam-power, when used for carbide production on a small scale; it being assumed that the difficulties and costs of distributing carbide will limit the area of effective competition from the factories established at the great centres of water-power.

The estimates are based upon the power and raw materials required for 1,000 kilograms of carbide, and the yield of carbide per kilowatt-day of 24 hours is taken as 5 kilograms.

The gross HP. necessary to yield a 1,000 kilograms of carbide per day is therefore 340, or allowing for all losses in the generating machinery, 450.

Taking these figures as the basis of his calculations, the Author arrives at the following results for a 450-HP. plant:—

—	Water-fall.			Steam.			River-flow.		
	£	s.	d.	£	s.	d.	£	s.	d.
Capital outlay	6,750	0	0	2,800	0	0	3,750	0	0
Annual running charges . . .	675	0	0	1,464	0	0	1,000	0	0
Daily running charges. . . .	2	5	0	4	18	0	3	7	0
Cost of 1 E.H.P. year at the electrodes of furnace . . .	2	10	0	5	8	0	3	14	0

Adding to these costs of power, the cost of raw materials and labour, the total costs for the production of 1,000 kilograms of carbide by the three sources of energy named above, work out to—

	£	s.	d.
Water-falls	8	18	0
Steam	11	14	0
River-flow	9	15	0

The Author gives no detailed estimates for the cost of carbide with gas-power, but he is of opinion that the use of blast-furnace gases for this purpose will undergo great development in the near future.

J. B. C. K.

Fuel Economy of Steam Engines for Traction.

R. C. CARPENTER.

(Street Railway Journal, November, 1899, p. 801.)

(Paper read before the New York State Street Railway Association.)

The results are given of thirty-five tests of electric railroad power stations made under the ordinary conditions of operation in which the economy is affected to a great extent by variation in load, and by poor or good firing; the latter often makes 20 per cent. or more difference in fuel economy. The steam consumption at normal steady load of 120 I.HP. by a simple non-condensing automatic slide-valve engine was slightly over 27 lbs. of steam per I.HP., nearly 30 lbs. at 150 HP., 44 lbs. at 60 HP., and 64·3 lbs. at 40 HP. The average results show a consumption only about 25 per cent. higher than obtained with this class of engine under most favourable conditions, or about 34·3 lbs. of steam and 4·63 lbs. of coal per I.HP. hour. With non-condensing simple Corliss engines under favourable conditions 23 lbs. to 25 lbs. of steam might be used per I.HP., while the average of the tests under working conditions, being slightly over one-half of the rated capacity, was 28·3 lbs. per I.HP. hour.

Reducing test results to uniform evaporation, the compound non-condensing engine was 9·4 per cent. more economical in use of coal, and about 5·5 per cent. more economical in use of steam than the simple non-condensing engine. The compound non-condensing engine under best load conditions would use 22 lbs. to 23 lbs. of steam, or nearly 33 per cent. less than under power-house conditions, but the data for this deduction are limited.

The compound condensing slide-valve or high-speed automatic engine uses 15 lbs. of steam under favourable load conditions, but under working conditions the consumption would be 30 per cent. or 40 per cent. more. Compound condensing Corliss, Greene, McIntosh and Seymour, and engines having similar valve motions, consume 15 lbs. or less with favourable load, which is increased by about 20 per cent. under working conditions. The average boiler evaporation from and at 212° was 10·26 lbs. for stations using simple non-condensing engines, 9·82 lbs. for stations using compound condensing slide-valve engine, and 10·54 lbs. for stations using compound condensing Corliss engines per lb. of fuel. The estimates of the cost of plant are exclusive of real estate, buildings, and chimneys, and the estimates of working expenses do not include wages and oil. The Author concludes from the tests that compound condensing low-speed engines with improved valve gear are much the better investment.

Summary of Tests.

Simple Non-condensing Slide-valve Engines.

No.	HP. of Engine.	Steam per I.HP. Hour.	Actual Coal per I.HP. Hour.	Mean Observed I.HP.	Per cent. Observed HP. to Capacity.	Boiler Evaporation per lb. Combustible from and at 212°.	Kind of Coal.
6	200	34·8	4·47	110	55	11·50	Pea A
1	405	34·5	6·54*a*	257	63·4	9·11*a*	Culm, East Ohio
7	1,975	35·7	4·60	862	51	9·46	Bit. W. Pa.
11	300	37·3	4·49	90	44	12·20	Bit.
11	300	34·3	4·72	95	46·7	10·20	Bit. Ill.
24	1,000	31·8	5·38*b*	717	71·7	9·15*b*	Bit.
31*c*	270	41·5	5·50*c*	126	47·5	10·60*c*	Ant. Buck.
33	270	31·6	4·61	147	54·5	10·70	Ant. Pea
Average . . .		35·1	5·07	..	54·2	10·24	
Average neglecting *c*		34·3	..	..	..	..	
Average neglecting *a b c*		..	4·63	..	..	..	

Remarks.—Engine in test (31) in bad condition. Probable average coal per I.HP. hour, when using anthracite or eastern bituminous, 4·63 lbs.; anthracite culm, 6·54; western bituminous, 5·38. Coal per kilowatt output averages 50 per cent. higher, or 6·94, 9·81, and 8·07 respectively. Probable error for any given case not over 10 per cent. Steam pressure, 90 lbs. to 120 lbs.

Simple Non-condensing Corliss Engine.

No.	HP. of Engine.	Steam per I.HP. Hour.	Actual Coal per I.HP. Hour.	Mean Observed I.HP.	Per cent. Observed HP. to Capacity.	Boiler Evaporation per lb. Combustible from and at 212°.	Kind of Coal.
17	300	30·1	3·09	139	46	11·45	Clearfield Bit.
19	150	26·9	3·5	90	60	9·73	Ant. Buck.
22	350	28	3·77	153	44·7	8·55	Ohio Bit.
Average . . .		28·3	3·45	..	50·3	..	

Compound Non-condensing Engine.

No.	HP. of Engine.	Steam per I.HP. Hour.	Actual Coal per I.HP. Hour.	Mean Observed I.HP.	Per cent. Observed HP. to Capacity.	Boiler Evaporation per lb. Combustible from and at 212°.	Kind of Coal.
2	1,000	30·5	4·22	603·5	60·3	9·03	Bit. 3 parts Ant.
4	1,250	36·8	4·33	674	53·8	9·92	Culm, 1 part. Bit. slack.
21	400	34·20	4·17	203	51	10·23	Bit. Penn.
24	1,200	30·37	4·93	754	62·7	9·01	Bit. Ill.
Average 21 and 24		32·38	4·55	..	..	..	

Remarks.—Test No. 2 was made on three simple engines 150 HP., one cross compound 250 HP., and one triple 300 HP. Test No. 4 was made on three simple engines 250 HP. each, and one compound of 500 HP. Steam pressure, 100 to 125 lbs.

Compound Condensing Slide-valve or High-speed Automatic Engine.

No.	HP. of Engine.	Steam per I.HP. Hour.	Actual Coal per I.HP. Hour.	Mean Observed I.HP.	Per cent. Observed HP. to Capacity.	Boiler Evaporation per lb. Combustible from and at 212°.	Kind of Coal.
3*a*	600	29·4	4·43	174	29	10·38	3 parts A; 1 pt. Bit.
3	600	23·2	3·50	190	32	9·93	1 part Bit.
8	400	20·2	3·14	154	38	8·29	Ohio Bit.
8*b*	400	16·7	2·40	180	45	7·75	Ohio Bit.
13	250	24·6	2·95	86	34·5	10·51	Bit. Penn.
16	350	22·7	3·41	164	47	9·50	Ant. Pea
18	1,200	25·6	3·61	904	75	10·58	Pea Penn.
21	400	29·3	3·81	188	47	10·23	Bit.
Average . . .		23·96	3·41	..	..	9·64	
Average except 3*a* and 8*b* . . .		24·26	3·40	..	..	9·82	
Average omitting 3*a*, 18, 21 and 8*b*		22·7	3·25	..	..	..	

Steam pressure 100 lbs. to 130 lbs.

COMPOUND CONDENSING, CORLISS, GREENE, MCINTOSH AND SEYMOUR, AND SIMILAR VALVE MOTIONS.

No.	HP. of Engine.	Steam per I.HP. Hour.	Actual Coal per I.HP. Hour.	Mean Observed I.HP.	Per cent. Observed HP. to Capacity.	Boiler Evaporation per lb. Combustible from and at 212°.	Kind of Coal.
10	825	22·7	4·06	482	58·2	8·29	{½ Bit. Slack. ½ A Culm.
14	1,000	21·9	2·56	277	27·7	10·96	Bit.
14	1,000	20·0	..	314	31·4	10·96	
28	350	16·64	2·10	182	52·2	11·80	Bit.
27	500	16·90	2·61	290	58	9·36	Bit.
30	2,000	14·50	1·80	814	40·7	10·70	Bit.
34	200	17·30	2·91	145	72	11·14	Bit.
35	1,600	20·50	2·18	..	..	11·14	Bit.
Average . . .		18·8	2·60	..	..	10·54	

Evaporation, 7·25 to 1 of coal.

Average omitting No. 10 . . .		18·25	2·36	..	..	..	

Evaporation, 7·78 to 1 of coal.

SUMMARY OF AVERAGE RESULTS.

Class of Engines.	Steam per I.HP. Lbs.	Coal per I.HP. Lbs.	Steam per I.HP. Lbs. Best Load.	Proportional Value of Engine.	Probable Coal per kw., lbs.
(A) *Non-condensing.*					
Slide valve simple, average .	34·3	4·63	30	53·1	6·90
Best result	31·6	4·61	..	..	..
Corliss simple, average . . .	28·3	3·45	25	64·5	5·65
Best result	26·9	3·01	..	..	..
Slide valve, compound, average	30·37	4·17	22	60·2	6·12
(B) *Condensing.*					
Slide valve, compound average	22·7	3·25	16	80·5	4·57
Best result	16·7	2·40	..	..	3·60
Corliss, compound average . .	18·2	2·36	15	100	3·64
Best result	14·5	1·80	..	..	2·70

COST PER HP. OF 500 HP. PLANT.

—	Boiler HP. per Engine HP.	Cost per HP. in Dollars. Engine.	Boiler.	Pumps and Heaters.	Piping, &c.	Total per I.HP.	Cost for 500 HP. Plant.
Non-condensing Engines.							
Simple slide valve . .	1·135	8·00	13·60	2·00	5·00	28·60	14,300·00
Simple Corliss . . .	0·933	12·00	11·20	2·00	5·00	30·20	15,100·00
Compound slide valve .	1·00	11·00	12·00	2·00	5·00	30·00	15,000·00
Condensing Engines.							
Compound slide valve .	0·75	11·00	9·00	4·00	6·00	30·00	15,000·00
Compound Corliss . .	0·602	16·00	7·25	4·00	6·00	33·25	16,625·00

FUEL AND INTEREST CHARGES FOR THE DIFFERENT CLASSES OF ENGINES.

—	Coal per I.HP. Hour.	Tons per HP. per Year. Day 12 Hours.	Day 18 Hours.	Day 24 Hours.	Fuel Cost per Year. 18 Hours per Day. $2 per Ton.	Interest and Depreciation, 8 per Cent.	Total Cost per Year per HP.
Non-condensing Engines.					$	$	$
Simple slide valve, average .	4·63	10·4	15·21	20·28	30·42	2·29	32·71
„ „ „ best . .	4·60	10·7	15·10	20·14	30·20	2·29	32·49
Simple Corliss, average . .	3·45	7·55	11·33	15·10	22·66	2·42	25·08
„ „ best . . .	3·01	6·59	9·89	13·18	19·78	2·42	22·20
Compound slide valve . .	4·17	9·05	13·57	18·10	27·14	2·40	29·54
Condensing Engines.							
Compound slide valve, average	3·25	7·12	10·68	14·24	21·36	2·40	23·76
Compound slide valve, best .	2·40	5·25	7·88	10·51	15·76	2·40	18·16
Compound Corliss, average .	2·36	5·17	7·74	10·33	15·48	2·64	18·12
„ „ best . .	1·80	3·94	5·91	7·88	11·82	2·64	14·46

J. T. R.

Niclausse Water-tube Boiler. M. Robinson.

(Electrical Engineer, October 13, 1899, p. 456.)

Compared with the Babcock-Wilcox land type and the Yarrow, Thornycroft, and Belleville marine boilers, the Niclausse boiler possesses features which make it a distinct type. Composed of tubes of 3 inches to 4 inches diameter, slightly inclined from the horizontal, it has headers only at one end of them, the other end being left free, so that there is no rigidity to resist expansion lengthwise. The free end of the tube is closed with a screwed cap, and the front end is secured by two coned joints to both outer and inner walls or faces of the header, but communicates only with the inner of two chambers or passages into which the header is divided by a partition. The outer passage is in communication with a number of smaller tubes, one of which is inserted concentrically into each of the larger generating tubes, for circulation of water. At the top of the header is the steam drum, and as the water-level in it is some distance above the header, circulation commences as soon as heat is applied to the tubes. This does not take place in such boilers as Thornycroft's where the tubes deliver steam above the water-line. The water flows down the outer or downcast half of the Niclausse header, through the small inner tubes, which project nearly the full length of the generating tubes, and back by the outer tubes, the steam and foam escaping by the upcast half of the header. The tubes are connected "in parallel," as in the Babcock-Wilcox boiler, and not "in series," as in the Belleville, so that the circulation is freer than in the latter. The constructive details have been arranged with a view to ease of examination and repair. Originally constructed in France, this boiler has done well in vessels of the navy there and on shore. Since its introduction into the Royal Navy and some electric-light installations in England improvements have been made in details. In the trials of the boilers of the "Temeraire," on land, an evaporation of 11·25, 10·12, 10·72 and 10·3 lbs. of water from and at 212° F. per lb. of coal was obtained with draught of 1·1, 1·5, 2·7 and 4·3 inches of water respectively, the lbs. of steam evaporated per square foot of heating surface having been 4·6, 10·6, 13·2, 15·9 for the different rates of combustion.

Experiments made in Paris on the comparative value for evaporation of the successive stages of tubes in a model boiler showed that nearly a quarter of the whole evaporation was due to the first row, and nearly a half to the first three rows which had 7·5 square feet of heating surface for each square foot of grate. The first six rows, with a surface ratio of 15 to 1, evaporated nearly two-thirds of the whole, and the last, or twelfth row evaporated only about 3¾ per cent. The value of additional surface can thus be estimated.

F. J. R.

F. H. Smith's System for Gas- and Oil-Engines.

(Feilden, October, 1899, p. 366.)

The horizontal gas-engine invented by F. H. Smith is of the two-cycle type, giving an explosion every revolution, and is designed to occupy small space and have simple mechanism. The exhaust gases are expelled and the new charge drawn in by an auxiliary piston during the end of the explosion and the early part of the compression stroke. The engine has no pretensions to ultimate design, and is illustrated by an external view and longitudinal section of a working model, the cylinder only 2½ inches diameter and the stroke 3 inches. An indicator diagram, taken at full load, shows compression 28 lbs. and maximum explosion pressure 132 lbs. per square inch above the atmosphere. The main piston, joined to the crank shaft by a connecting rod, is hollowed out to receive a guide tube fixed to the inner piston next the combustion chamber. Inside the tube there is a strong spiral spring which connects the two pistons and works the inner one. The gas and air inlet port near the crank end of the cylinder is closed and opened by the main piston. During the explosion-stroke the two pistons are forced out together, compressing the spiral spring between them. When the exhaust valve is opened by a lever and cam on the crank shaft, the inner piston is sprung back rapidly, by the compressed spring, to the combustion end of the cylinder, driving out the exhaust gases, and at the same time drawing in the new charge between the two pistons. On the return stroke of the main piston the inlet port is closed and the charge is compressed through the non-return valve in the inner piston into the combustion-chamber. Electric ignition of the charge takes place just before the dead centre, and the explosion drives the pistons out together again.

The inner piston, actuated by the spiral spring, controls the speed of the engine. The amount of the charge drawn in is regulated by the time taken by the inner piston in traversing the cylinder. When the load is suddenly thrown off the engine, though the speed may be momentarily accelerated, the inner piston has not time to complete the full journey to the farther end of the cylinder, and therefore a smaller charge is taken and added to a larger residue of burnt gases as a diluent for a weaker explosion. Consequently the speed gradually slows down automatically.

Only the combustion-chamber end of the cylinder is cooled by a water-jacket. The weak point in the design appears to be the spring which actuates the inner piston. The inventor states that after running for several months the spring in the model had not altered in any way, the cold charge passing round every revolution keeping it cool.

W. R.

Switches and Circuit Breakers.

BRUNSWICK, VEDOVELLI, ZETTER, BOUCHEROT, HILLAIRET, GROSSELIN, KORDA.

(Soc. Int. Élect., Bull., 1899, p. 7 *et seq.*)

These Papers form a discussion on the relative merits of various switches for high and low tension circuits.

If interrupters of all kinds are only opened when the current is zero the nature of the metallic surfaces in contacts is immaterial provided the contact is sufficiently good. This is not the case if a current is flowing at the instant of break so as to give rise to sparks or arcs. In this case the choice of the metallic surfaces is a matter of considerable importance. Certain metals and even certain forms of contact surface are better than others in the prevention of the formation of arcs. Recent researches on arcs between metallic electrodes show that certain substances tend to stifle the arc. Zinc tends thus to stifle an arc, as also brass, but to a less extent. For high pressures it is advisable to open switches in oil.

W. G. R.

Size of Motors for Driving in Workshops.

(American Institution of Electrical Engineers, Transactions, 1899, p. 163.)

This topical discussion dealt with the question of subdivision of the motor equipment of electrically driven works, from the points of view of capital outlay, economy of power and convenience. G. S. Dunn submitted data and curves showing that the direct saving of power effected by substituting three small motors for one large motor of equivalent power was trifling, but the indirect saving due to the idle periods of machines ranges from 15 per cent. to 50 per cent. The cost of three motors compared with that of one is 70 per cent. greater when the total power is 2 HP., 28 per cent. greater for 50 HP., and 2 per cent. less for 100 HP. In at least one-half of the cases met with the question of convenience is paramount, and the gain in this respect far outweighs considerations of cost or economy. As the energy expended costs only from 0·5 per cent. to 1·8 per cent. of the value of a finished product, economy of energy is in any case unimportant. The absence of belts confers great benefits on workshops; the output of the Government Printing Office in Washington, the running expenses of which are £2,200 a day, was increased 15 per cent. by the adoption of direct-coupled motors throughout. Preference is given to small motors down to a limit of 5 HP. for light, and 10 HP. for heavy machines. R. T. E. Lozier confirmed these statements, and gave practical details of the results of experience with a separate motor for each tool, showing amongst other things that the cost of

repairs is small. No general rule can be laid down as to the use of direct-coupled *v.* geared motors. H. W. Leonard advocated the use of a four-wire distribution system, giving six different pressures for efficient speed regulation, and described a three-wire system with + or — booster, as well as a motor-dynamo system of delicate control at low speeds. G. Hall pointed out that very small ($\frac{1}{10}$ HP.) motors fall in speed as their temperature rises, and are therefore not always satisfactory. In a certain case, where 14,000 books were manufactured per day, at a fuel cost (for power only) of £9, the adoption of motors increased the output to 22,000 books per day, while an outlay for fuel of £1 14*s.* per day covered the cost of power, lighting, and operating the elevators in a twelve-storey building. Instances are given of the saving in power due to the abolition of belting, and extreme subdivision of the motors was advocated. H. B. Coho described a case where it was preferred to drive 100 sewing machines with separate motors, at heavy cost, in order to avoid liability to break down. O. Smith recommended a separate motor to each machine down to a limit of 2 HP., and gave details of his experience, stating that a 3 HP. motor could easily work up to 15 HP. momentarily. G. S. Dunn pointed out that H. W. Leonard's system did not apply to cases where constant power with varying torque and speed was required; for this, mechanical gearing was necessary. A. Williams emphasised the necessity of co-operation between the makers of motors and of the machines to be driven, and put the lower limit of subdivision at $\frac{1}{2}$ HP. J. M. Smith said that in scarcely any factory are one-third of the machines in operation at one time; the great economy of electrical transmission is due to the stoppage of the motors when the machines are idle. A. Williams added a number of data of shaft losses, varying from 18 per cent. to 68 per cent., and G. Hill stated that in numerous tests he had never found less than 50 per cent. loss.

A. H. A.

Armature Reaction in Alternators. A. Blondel.

(Comptes Rendus de l'Académie des Sciences, October 16, 1899, p. 586.)

Considering the case of a polyphase alternator symmetrically loaded, the Author points out that the actual armature reaction corresponding to a given phase displacement may be regarded as made up of (1) an opposing magnetic flux due to the idle component of the current; (2) a cross-flux due to the load component. So long as the magnetisation is well below saturation, the effect of armature reaction may be expressed in terms of two coefficients of self-induction, l (corresponding to load current) and l^1 (corresponding to idle current), by the vectorial equation—

$$E_a = \overline{rI} + \overline{lpI \cos\psi} + \overline{l'pI \sin\psi},$$

where E_a is the drop of potential due to armature resistance and reactance, r the resistance of the armature, and ψ the phase-difference between the electromotive force and current. The vectors $\overline{lpI \cos \psi}$ and $\overline{l'pI \sin \psi}$ are in quadrature with the currents I cos ψ and I sin ψ respectively, while $\bar{r}I$ is in phase with I. In cases where the permeability can no longer be regarded as constant, we must, instead of considering l', determine the magnetomotive-force corresponding to it, and compound this with the magnetomotive-force due to the field winding.

A. H.

Weston Winding for Three-wire Dynamos. A. Sengel.

(Elektrotechnische Zeitschrift, 1899, p. 525 *et seq.*)

By placing a third brush half-way between the main brushes of a dynamo, two circuits, each at a P.D. equal to half the terminal P.D. of the machine, may be supplied. Such an arrangement may be used in connection with a three-wire distributing system. The difficulty due to sparking at the intermediate brush may be overcome in various ways. The Author points out that armatures provided with a Weston winding—*i.e.*, one consisting of two (or more) independent closed windings, the commutator segments of the one winding being sandwiched in between those of the other—are especially suitable for this purpose. The main brushes of the machine must in this case cover as many commutator segments as there are windings. By making the third brush only wide enough to cover a single segment, short-circuiting of single coils by this brush is prevented. When running on open circuit a certain amount of sparking at the intermediate brush still takes place, on account of the differential action between the two branches of the winding which connect each main brush with the intermediate one. The Author made the singular discovery that the amount of sparking is dependent on the polarity of the pole-piece under which the intermediate brush is placed, a good deal more sparking taking place when the current passes from the brush to the receding commutator segment than when the reverse arrangement is adopted. When the machine is loaded on one side only, its behaviour with regard to sparking depends on whether the load circuit is between the intermediate brush and the main brush in advance of it, or the intermediate brush and the main brush behind it. In the former case the sparking decreases with increase of load up to a certain limit, at which it practically vanishes and beyond which it reappears. In the second case the sparking steadily increases with the load. These effects may be explained by considering the armature reaction and current distribution in each case. The Author concludes from his experi-

ments that when carbon brushes are used, machines constructed on the above plan are capable of giving good results when used on a three-wire network on which the want of balance does not exceed 20 per cent.

A. H.

Induction Motors. C. A. Carus-Wilson.

(Electrical Review, October 27, 1899, p. 697.)

(Lecture delivered before the Royal Institution, April 28, 1899.)

The theory of the alternating current motor was illustrated in an interesting way by aid of the oscillograph, the Author showing that the law of force variation, with synchronously varying field and current, was such that two series of impulses at right angles gave a uniform impulse when acting together. It was thus possible to construct an alternating current motor in which the sum of the turning moments on the shaft was a constant quantity; the well-known induction motor giving such a result.

The rotating magnetic field of the induction motors was illustrated by an experiment in which a small permanent magnet carrying a mirror was centred upon a vibrating rod placed between two pairs of electromagnets. When two opposite magnets were excited the mirror vibrated between them and reflected a spot of light on to the screen, tracing out a vertical line. When the second pair of opposite magnets was excited the spot traced out a horizontal line of equal amplitude. Both sets were then excited together by currents in step with each other, with the result that the spot vibrated in a line, making an angle 45° with the former lines of vibration. When, however, the exciting currents were made to differ by one-quarter of a period the spot of light reflected from the mirror described a circle, showing that the magnetic field produced by two magnets set at right angles, and excited by two currents differing by a quarter of a period, is of uniform intensity and rotates at a uniform rate.

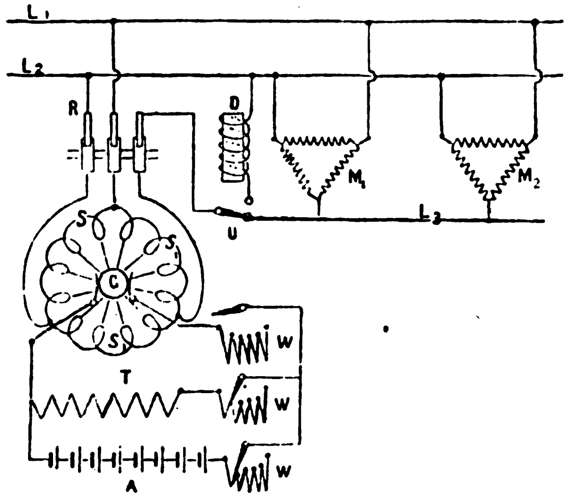
E. K. S.

Starting Device for Synchronous Phase-Transformer.

(Elekt. Runds., July 1, 1899, p. 221.)

The arrangement of connections (used by Schuckert and Company) is shown in the accompanying sketch, in which L_1, L_2 are the single-phase supply mains, and M_1, M_2 three-phase induction motors connected between L_1, L_2, and a supplementary main L_3, which receives current from the windings S_1 of the phase transformer. The latter may take the form of an ordinary rotary converter, and will run as a synchronous motor when supplied

with single-phase current, developing the phase-displaced currents required by the motors. Two methods of starting the phase transformer may be used. The first consists in producing a phase-displacement between the currents in S and those in S_1, by means of a choking-coil D, so as to obtain a rotating field in the armature;



the field coils T being short-circuited the transformer will start. But since it could never be brought up to synchronous speed by this method, a device for temporarily halving the number of field-poles is provided; the transformer may then be run up to a speed above synchronism, the current switched off, the normal field connections restored, the current switched on at synchronism, and the field excited. In order to prevent sparking when the transformer is self-exciting, a steadying secondary battery is used. This latter, however, also provides another method of starting, by enabling the transformer to be run up to synchronous speed as a simple continuous current motor.

A. H.

Working Costs of Isolated Electrical Installations.

P. R. Moses.

(American Institution of Electrical Engineers, Transactions 1899, p. 325 *et seq.*)

This Paper deals with the cost of electricity in typical buildings in New York City, U.S.A., as compared with the cost of supply from central stations. The cost of electricity is defined as the difference between the cost of supplying the other requirements of

the building alone, and the cost of supplying both these and electricity from private plant. Interest and depreciation are included at 5 per cent. each. Numerous load curves, taken from various types of building, and a mass of data in connection with the detailed costs of operation, are given. A few of the results are summarised below:—

Type of Building.	Total Cost per Kilo-watt-Hour.	Coal per Kilowatt-Hour.	Kind of Load.	Approximate Annual Kilo-watt-Hours.
	d.	lbs.		
Large hotel	0·83	3·4	Fluctuating	825,000
Small "	1·22	8·37	Steady	100,000
Apartments	2·35	7·0	"	55,000
Large store	1·42	9·25	"	200,000
Small "	2·05	12·8	"	50,000
Large office building . . .	2·18	9·4	Fluctuating	158,000
Small " " . . .	2·53	7·25	"	40,000
Loft building	1·30	8·0	"	100,000

The average price of electricity supplied from the Edison central stations was 5·3*d.* per kilowatt hour during 1898. Full details are given of the methods of obtaining the necessary data and of the installations themselves.

In the discussion H. W. Leonard preferred 15 per cent. for interest and depreciation, and pointed out the value of the space occupied by the plant. A. Williams remarked that exhaust steam for heating was required in the morning, but not in the evening, when the supply was at a maximum, and gave instances where the station supply was proved to be the cheaper, and where the energy actually generated was far less than had been believed. He also disputed various conclusions of the Author, and gave instances of gas-driven plants, of which the cost of working exceeded the central station charges. C. P. Steinmetz said that for the greatest economy, elevators should be balanced so that the motor overcomes the friction only. In a communication C. Blizard supported the use of storage batteries in isolated plants.

A. H. A.

Electric Transmission between Bozen, Meran, and Neighbourhood.

O. von Miller.

(Elektrotechnische Zeitschrift, August 31, 1899, p. 615.)

Detailed description of an important three-phase transmission plant laid down by Ganz and Co. The power station is situated 5 kilometres from the town of Meran (Austrian Tyrol), and is equipped with six turbines, each of 1,000 HP., working under a head of water of about 66 metres. The three-phase alternators

are direct driven at 320 revolutions per minute, and each is fitted with a four-pole exciter. Four of the alternators generate current at 3,600 volts, and two are arranged to give either 3,600 volts or 10,000 volts, the latter pressure being required for the long-distance line between Meran and Bozen. The switchboard is so arranged that two of the alternators can be connected on to the 3,600 volt 'bus bars for the electric lighting of Meran, or on to 3,600 volt special 'bus bars for power to a carbide factory.

The disposition and lengths of lines and the amount of energy required for lighting and power is as follows :—

Three-phase line at 3,600 volts for Meran and Neighbourhood.
" " " 10,000 " for Bozen and Zwischenork.
" " " 3,600 " for the electrochemical factory.

Area of each of the three conductors to Meran 6·5 square millimetres, and to Bozen 6 square millimetres.

Total length of main transmission line, 39 kilometres.
" " overhead distributing cables, 30·4 kilometres.
" " underground cables, 88·2 kilometres.

Street lighting, 83 arcs, 770 incandescents.
Private lighting, 21 arcs, 24,500 incandescents.
Motors, 45 HP.
Electrochemical factory, 2,000 HP.

A very clear diagram of connections of the power-house main switchboard is given, and the plan and elevation of the station indicate the ample space which is provided behind the board for the extra high tension switches and 'bus bars, Siemens-Halske horn lightning arresters, etc.

Three cross-sections are given of the transformer sub-station at Gries, near Bozen, where the pressure is reduced from 10,000 to 3,000 volts, and six cross-sections of a street switch pillar.

The charge for light has been fixed at 7 florins (11*s.*) per 16 candle-power lamp per annum, and for motors at 50 florins (£4) per HP. per annum.

E. K. S.

Buffer Batteries for Electric Traction. L. Gebhard.

(Zeitschrift Elektrotechnischer, Wien, 1899, p. 418 *et seq.*)

This is a Paper read before the Elektrotechnischer Verein, Wien. In designing traction stations it has been usual to make the dynamos large enough to take the maximum loads allowing a suitable stand-by, and to use a battery merely to regulate the voltage and supply the light load when the plant is shut down. It is then an extra capital charge, and is therefore made as small as possible. The true use of the battery is rather to allow the

plant installed to be reduced till it is just sufficient to take the average load, relying on the battery to supply the additional demand and to act as the necessary stand-by, thus keeping the load factor at 100 per cent., and effecting a large saving both in capital outlay and in generating expenses. A specimen traction-load curve taken from the Remscheidt station is given. In large stations the advantage of a buffer battery is not so marked owing to the more even load curve demanded. In Hamburg, for instance, with an average load of 2,000 amperes, the maximum momentary output reaches only 2,400, which could easily be obtained as an overload from a 2,000 ampere plant. But even here the avoidance of sudden shocks on the generators is very advantageous, and a battery with a capacity of 1,600 amperes for one hour has been installed. In Leipzig, in spite of the large output, a saving of 30 per cent. was effected in the generating expenses by the installation of a battery of similar capacity. A graphic method is described for determining the periodic variations in the load curve, and thence the average load, from the profile of the line and the schedule of the service of cars. To determine the HP. required by a car at any moment the following formula is given :—

$$\text{HP.} = \frac{6\omega v\,(1 \cdot 25\mu + \text{S})}{\text{E}}$$

Where μ, S and E are the traction coefficient, the gradient and the efficiency of the motors and gear, all expressed as percentages, ω the weight of the car in tons, and v the speed in miles per hour. The coefficient $1 \cdot 25$ is introduced to cover variations in the condition of the track, losses in the starting and regulating resistances, etc. The traction coefficient μ may usually be taken as $1 \cdot 2$ per cent.

From this graphic solution the following rule is demonstrated: the average power required for all the cars on a given track can be found by dividing the work required to propel one car for the double journey by the scheduled times in seconds between the cars. And this is the maximum output required from the dynamos if an efficient buffer battery is employed. It should be large enough to supply this average load itself for one hour, and its internal resistance, which depends largely on its capacity, should be small enough to keep the voltage from falling too low on a momentary rush of current. The drop of voltage owing to the battery resistance should not be more than 5 per cent. when giving an extra output equal to the average output of the plant. These conditions determine the size of battery required.

For all gradients less in magnitude than the traction coefficient the power used in going up is saved in the descent on the return journey. Hence the calculation of the average power required can be simplified without reducing its accuracy by neglecting all such gradients. The loss of power in the starting and regulating resistances is not taken into account in the above formula. But

such losses are amply covered by the 25 per cent. allowance in the traction coefficient, particularly if the stopping-places are sufficiently definite to avoid frequent unnecessary use of the brake.

Details are given of the capital and working expenses estimated for a 4-mile tramway between Haspe and Gevelsberg, in Westphalia, showing the great economy attained by the use of a large battery.

L. B.

Multiple-unit System for Electrical Railways.

F. J. Sprague.

(American Institution of Electrical Engineers, 1898, p. 211 *et seq.*)

The Paper describes of the multiple-unit system of electric traction as applied to the South Side Elevated Railway of Chicago. Each unit or coach of the train is equipped with its own motors and controllers, the latter being actuated by means of small pilot motors which are in turn controlled by the driver in the leading coach.

Some of the advantages of the arrangement are:—

The motor equipment is directly proportional to the number of car units.

Each car being lighted, heated, and braked independently, it has independent movement in yards, car houses, or on the tracks.

Cars can be added to or taken from a train in about a third of the time that is possible with a locomotive system.

The fullest use can be made of sidings and tracks for storage and inspection.

The hammering of rail joints, etc., is diminished because of the less weight per driving wheel.

Increasing the number of motors on the train gives more room for increase of dimensions of essential working parts, such as bearings, gears, and commutators of any one motor; also greater space for the application of brakes—electric and mechanical.

When the total motor capacity, say 600 HP., is concentrated on one car of a six-car train, there is not the same ratio of weight on the drivers, and consequently a much smaller effective pull than with many smaller motors distributed over all the six cars of the train.

The discussion took the form of a series of questions, to each of which the Author very ably replied. In replying to the suggestion that the controlling mechanism was intricate, the Author stated that experience showed very little liability of the small pilot motors to get out of order. He pointed out that the cost of plant per HP. in the generating station is about ten times what it is for the train equipment. It is therefore economical to expend money on the motors, controllers, etc., if by so doing the total HP. of the generating plant can be reduced.

In referring to the chloride accumulator battery which has been installed on the South Side Elevated Railway, the Author said he was an advocate of the storage battery for regulation and taking the peak loads, if it was put in under proper guarantees.

E. K. S.

Electrical Train-lighting. AUVERT.

(Revue générale des Chemins de fer, August, 1899, p. 57.)

The various systems hitherto employed for train-lighting by electricity are noticed. The Author then describes a new system which is being employed experimentally by the Lyons Railway Company of France. It resembles the Stone system in having a dynamo and battery on each car, but the method of regulation is unique. The dynamo is driven by a friction wheel from the inside face of a carriage wheel, and its speed varies with that of the train. It is excited by a constant current from the battery, which also feeds the lamps when the speed is too slow. As the speed rises an automatic switch throws the dynamo into parallel with the battery. A commutating device changes over the dynamo connections if the direction of the train's motion be reversed. The current in the main circuit is regulated to a constant maximum value by being passed through a small series wound motor, whose spindle carries a brake pulley and brake whose pressure can be adjusted. If the dynamo current rises above a certain maximum value the motor overcomes the resistance of the brake and rotates, introducing the necessary back electromotive force to keep the current constant. This maximum current is sufficient to feed the lights and charge the battery. As the speed falls the charging current first falls, then becomes a discharge, and at a lower speed still the dynamo is automatically cut out and the whole current supplied from the battery. The lamps can be "turned down" by putting two in series, a compensating resistance being put in parallel to keep the load steady. The carriage is lit by thirteen 9 candle-power lamps taking 1·22 amperes each at 15 volts, 16 amperes in all. The regulating motor brake is adjusted to give a constant maximum current of 28 amperes, the remaining 12 going to charge the battery, which has a capacity of 180 ampere hours. It consists of eight cells, weighing in all 460 lbs., and is able to supply the lights without the aid of the dynamo for 8 or 9 hours. The experimental carriage has been in constant service since March, 1899, having completed 18,000 miles satisfactorily. In a complete train only one dynamo in the brake van need be employed, with a battery and switching gear on each carriage.

L. B.

Standard Kilogram. M. Thiesen.

(Abstract in Zeitschrift Instrumentenk. vol. xix., October, 1899, pp. 312–317, from Trav. et Mém. du Bureau Intern. des Poids et Mesures, vol. viii., 1893, and vol. ix., 1899.)

The work of comparing the forty national standard kilograms with the international standards has now been finished. Instead of comparing all the national standards in every possible combination, they were divided into six groups of seven and seven groups of six, and all possible combinations were carried out within each group, thus diminishing the number of comparisons from 780 to 231. The standards, or "prototypes," were all made of an alloy of 90 per cent. platinum and 10 per cent. iridium. Their shape is that of a cylinder of height equal to its diameter. The density of each standard was determined by weighing in water. The comparison of each standard with the international standard was carried out by means of Runge's vacuum balance, provided with automatic changing device, and a device for automatically centring the cylinder on the cross serving as a scale. The probable error in the mass of each standard is 0·0020 milligram when compared with the mean of all national standards, 0·0022 milligram compared with the international standard, and 0·0028 milligram compared with any other national standard.

E. E. F.

Registration of Vertical Movements. N. Ach.

(Zeitschrift Instrumentenk. vol. xix., October, 1899, pp. 309–312.)

The vertical motions of the centre of gravity of a ship at sea are recorded photographically by means of an aneroid barometer carrying a mirror instead of a pointer. The limit of accuracy of the records is about 1 metre, which corresponds to an ordinate of about 2 millimetres on the curve. Greater accuracy can be obtained by means of a micrometric eyepiece, but not in the photographic records. The apparatus is suspended by a double Cardani suspension as used by Julius.

E. E. F.

Air-Resistance. G. H. Bryan.

(Nature, vol. lxi., November, 30, 1899, pp. 107–109.)

Deals with recent researches of Le Dantec and of Canovetti. As in 1893, Le Dantec makes the surface under test slide down a vertical wire. The start releases an electric recording device, and the current is broken when the body strikes the buffer at the end

of its descent, which occupied 1, 2, or 3 seconds. The experiments were conducted in the nave of a chapel; it is necessary to avoid all disturbance of the air, even by persons moving. A surface, 1 metre square, moving with a velocity of 1 metre per second, experiences a resistance of 81 grams; the form of the plate, circular, square, or triangular, is of importance—an observation made also by O. Mannesmann—and the resistance would appear to be proportional to the length of the contour. The law that, within certain limits, the resistance is proportional to the square of the velocity, is verified.

Canovetti suspends his bodies from a 3-millimetre wire, 370 metres in length, stretched along the slope of a hill in the open air. As the wire hangs in a catenary, the body was arrested 90 metres before reaching the end of the wire. But the weight of the body affected the curve, and the time was measured simply by watching a chronometer. Yet the observations seem to be of practical value, as he finds a resistance of 94 grams (instead of Le Dantec's 81 grams). In most experiments he employed circular, not square, plates, and attached long or short cones to the rear of the plate (resistance reduced to 60 grams), to both rear and front (resistance 15 grams), or a hemispherical cap to the front (resistance 22·5 grams), etc. He also tried bodies of the shape of a Chalais balloon, a long cone, and a hemisphere joined by their bases, enveloped in a net; the resistance was 80 grams, and largely due to the net.

H. B.

Aeronautics and Soaring-Machines. L. HARGRAVE.

(Royal Society, N.S. Wales, Journ. and Proc., vol. xxxii. 1898, pp. 55–65, and 209–222.)

These two Papers deal with experiments on soaring carried out on models. The Author differentiates between soaring and gliding. In the former a bird remains stationary, or it may be rises in a horizontal wind without flapping its wings, while in gliding the bird moves forward while slowly descending. Lilienthal's experiments were on gliding. The power which a bird has of soaring is attributed to the curved part of the wing nearest the body, there being a deep hollow on the under side of the wing, immediately behind the edge, which first meets the wind. The air dividing on this edge, part goes over the wing and part under, and this latter part generates a vortex in the deep hollow on the under side of the wing, which vortex causes a greater pressure on the under side than there is on the upper side, and so gives the lifting power. The Author considers the problem of the soaring bird as analogous to that of a ball retained in its position in front of a nozzle from which a high-pressure jet of water is issuing.

The models experimented with have curved surfaces representing

the curved parts of the wings, and also other surfaces to represent the plane tips of the wings and the tail, which are requisite to give stability; these latter surfaces are like those on a cellular kite. One form of model has a long tube as base, the ends of the tube being loaded with lead. To each end of this tube, on the upper side, is attached a circular cylinder of tin plate, the axis being parallel to the tube. These two cylinders and the rod form a cellular kite. Between the two cylinders the curved surface is attached. It is made from sheet vulcanite, the sheet being three or four times as broad as it is long. A vertical section of the bent sheet is circular at the forward end, the tangent at the very end being vertical; then when the tangent comes nearly horizontal the form changes to the hyperbolic, and maintains that form to the other end. This curved surface can be angled bodily to the rod. Several other forms of model are described.

In the experiments, the models are tethered by a cord to a horizontal cord stretched between the tops of two high poles. The models then take up a position to windward of the tethering-point, sometimes on a level with it, and sometimes above it.

J. B. H.

Thermal Conductivity of Vulcanite. B. O. Peirce.

(Philosophical Magazine, vol. xlix, January, 1900, pp. 15–31.)

To measure the conduction of materials like vulcanite or glass, prisms were built up consisting of plates of the material, separated by layers of tin-foil; the faces of the prism were kept in contact with a steam supply and a reservoir of ice. Thermocouples inserted between the plates gave the temperature gradient, and the amount of ice melted—the drip from the ice becomes steady when the experiment is continued for some hours—gave the flow of heat. The influence of the edges of the prism was shown to be negligible. The most suitable thermocouple consisted of thin strips of German silver and copper soldered end to end. The conductivity of vulcanite varies, according to the manufacture, from 0·000200 to 0·00317.

R. A. L.

Dark Lightning-Flashes. W. J. S. Lockyer.

(Nature, vol. lx., October 12, 1899, pp. 570–574.)

The Author here discusses the possibility and probability of the objective existence of dark flashes. He remarks at the outset that many apparent dark flashes as seen by the eye are probably due to retina fatigue, and so have only a subjective existence. Photography also may be deceptive, owing to the phenomenon of photo-

graphic reversal. A. W. Clayden, in 1899, put forward the following explanation of the apparent dark flashes shown by photography: If the lens be covered the moment after a flash has occurred, the developed image is always bright. If, however, after the flash has passed, the plate be exposed either to the continued action of a feeble diffused light or to the powerful glare arising from one or more subsequent flashes, then, on development, the image of the original flash will probably come out black. The present Author then proceeds to test this explanation as applied to a number of very striking photographs exhibiting bright and dark flashes. He also took photographs of sparks from an induction coil with and without subsequent exposure to light reflected from burning magnesium. The examination of all these cases leads to an entire corroboration of Clayden's hypothesis.

E. H. B.

Cause of Dark Lightning and the Clayden Effect.

R. W. Wood.

(Science, vol. x., November 17, pp. 717–721, and Nature, vol. lxi., November 30, 1899, pp. 104, 105.)

A. W. Clayden has explained the presence of dark lightning-flashes in photographs by the peculiar photographic reversal now known as the Clayden effect. The present Paper seeks the explanation of this effect, and finds it in the short duration of the initial flash. This renders the part of the plate acted upon less sensitive. Accordingly, the track of the flash in question comes out dark if, after the passage of the flash, the plate is further exposed to the continued action of light from ordinary sources. The Paper establishes these points by a series of experiments which are briefly as follows: The Clayden effect was repeatedly obtained from electric sparks, but could not be obtained when the filament of a glow lamp was substituted for the spark. This showed that the spark had something necessary to the effect sought which the incandescent filament lacked. It was next shown that this quality was not intensity. It was subsequently shown that the photographic reversal under examination did not depend upon the wave-length of the radiation used. It then occurred to the experimenter that the time element might be vital to the problem. The light of the spark used lasted $\frac{1}{50000}$ of a second, and might differ in its action from a weaker light of longer duration. This was first tested by photographing (1) a single spark passing through a capillary tube with the lens wide open, and (2) four such sparks superimposed on the plate, but with the lens stopped down to one-quarter of its former aperture. The plate was then fogged in the usual manner, and on development the single discharge was reversed, but the composite one was

not. To demonstrate conclusively that the time factor is the only one, the light from the crater of an arc lamp was focussed upon the point of coincidence of two slits. One of these was a radial slit in a disk driven at high speed, so as to give an exposure of $\frac{1}{55000}$ of a second. The anticipated reversal of the photographic image was obtained.

E. H. B.

Conductivity of Copper.

(Engineering, vol. lxviii., December 22, 1899, p. 804.)

This is the report of a committee formed of representatives of the Institution of Electrical Engineers, the General Post Office, and the principal manufacturers of rubber insulated cables to determine a standard of conductivity of copper.

The committee resolved: (1) That Matthiessen's standard of 0·153858 standard ohm resistance for a wire 1 metre long, weighing 1 gram at 60° F. be taken as the standard for hard-drawn high-conductivity commercial copper. (2) That hard-drawn copper be defined as that which will not elongate more than 1 per cent. without fracture. (3) That Matthiessen's standard of 0·150822 standard ohm resistance for a wire 1 metre long, weighing 1 gram at 60° F. be taken as the standard for annealed high-conductivity commercial copper. (4) That copper be taken as weighing 555 lbs. per cubic foot at 60° F., which will give a specific gravity of 8·912. (5) That Messrs. Clarke, Forde and Taylor's temperature coefficient, as published in their pamphlet, dated February 20, 1899, be adopted, and that an average coefficient of 0·00238 per degree F. be adopted for commercial purposes. (6) That the resistance and weight of conductors be calculated from the actual length of the wires. (7) That a lay of twenty times the pitch diameter be taken as the standard for the calculation of Tables. (8) That 2 per cent. variation of resistance or weight be allowed in all conductors. (9) That an allowance of 1 per cent. increased resistance, as calculated from the diameter, be allowed on all tinned copper between Nos. 22 and 12 gauges inclusive.

W. G. R.

Hissing of the Arc. Mrs. Ayrton.

(Institution of Electrical Engineers Journal, vol. xxviii., pp. 400–430. Discussion, 1899, pp. 431–450.)

A change taking place in the electric arc may manifest itself in three ways: (1) By emitting various sounds or by becoming silent; (2) By changes in its electrical measurements; and (3) By an alteration in the appearance of the crater, the arc, and the

carbons. The two sounds of the arc which possess significance are the hum and the hiss. The humming sound is heard when the arc is just on the point of hissing or ceasing to hiss, although it is possible for an arc to jump suddenly from the silent to the hissing state, or *vice versâ*. The Paper deals with the arc in this transition stage, viz., from silence to humming and from humming to hissing. No difference in the electrical measurements is noticed whether the arc is silent or humming. The hissing of the arc, which is accompanied by considerable changes, is dealt with more particularly.

Sets of curves are given for direct-current open arcs, showing the variation of the potential difference (between the carbons), with the current strength, for various constant lengths of arc, both silent and hissing. These curves show that:—

1. A silent arc of constant length may be made to hiss by increasing the current strength.

2. A silent arc with constant current may be made to hiss by shortening the arc.

3. When hissing commences the potential difference falls suddenly about 10 volts, and a sudden rise in current also takes place.

4. The largest current that will maintain a silent arc is greater the longer the arc.

5. For the hissing arc, the potential difference is constant for a certain length of arc, whatever the value of the current.

The Author proves from the curves of actual experiments that for each pair of carbons the current that will sustain a normal silent arc has a maximum value, and that any current greater than this will make the arc hiss, however long it may be. It is also shown that with the hissing, as with the silent arc, a straight line law connects the potential difference between the carbons with the length of the arc; the difference between the law for silent and for hissing arcs being that, with silent arcs the law holds only for constant currents or for currents at the hissing point, whereas with hissing arcs it holds whatever the current may be, since the potential difference between the carbons of a hissing arc is constant for a certain length of arc, irrespective of the current strength. Also from these curves it is shown that the longer the arc the less does the potential difference between the carbons diminish when it changes from silence to hissing.

Experiments were made on the distribution of the fall of pressure in the arc itself, Luggin's results of 1889 being confirmed, viz., that the maximum part of the diminution of potential difference is between the positive carbon and the arc itself. In a hissing arc about two-thirds of the total diminution is accounted for at this point, the remaining third appearing to be due to a lowering of the resistance of the arc itself. The Author found that the value of the smallest hissing current depended on the circuit outside the arc, or the sudden increase of current when hissing begins equals the product of the sudden diminution of the

potential difference into the conductance of the circuit outside the arc.

The electrical measurements of hissing arcs being dealt with, the Author next considers the appearance of the crater, arc, and carbons.

The different changes in appearance are described, from that of a low-current silent arc in which the current is gradually increased to that of a humming and finally a hissing arc. Illustrations are given showing the general shape of the carbons and the distribution of colours in the arc at these different stages. The most important change in the arc is on the commencement of hissing, when the negative begins to form a "mushroom" at its tip and the crater on the positive more than covers the tip of the carbon. The positive carbon changes to such an extent with different conditions of burning, that it is quite possible to state the conditions under which a normal arc has burnt from the appearance of the positive carbon. The hissing of the arc is caused by air coming in contact with the crater, and is due to the carbon burning instead of volatilizing. A silent arc is changed at once into a hissing arc when the flame of the arc leaves the end of the positive carbon and burns on the vertical sides, the air being able to enter the crater itself, thus producing the hissing by causing a part of the heated carbon to burn. This conclusion was arrived at after many experiments. With perfectly enclosed arcs no hissing could be produced; open arcs were made to hiss by having gases introduced into the crater of the arc through a tubular positive carbon. With air or oxygen thus admitted into an open silent arc all the peculiarities of a hissing arc were produced, and also, to a less extent, with hydrogen. With carbon-dioxide or nitrogen no hissing was produced. The same gases, when introduced into the crater of an enclosed arc, produced similar results, with the exception of hydrogen, which produced no hissing. With both open and enclosed arcs no hissing was produced by any of the gases when introduced through the negative carbon gently; but when forced through, hissing was produced and the arc blown out.

Another reason for believing that hissing is caused by access of air to the crater is that the green colour, seen on the outside only of a silent arc, is to be found inside in the case of a hissing arc.

The reading of the Paper was followed by a lengthy discussion.

E. D. P.

Properties of Iron. GALY-ACHÉ.

(Comptes Rendus, vol. cxxix., December 26, 1899, pp. 1230–1232.)

To explain the peculiar phenomena of the tempering of steel, Osmond and Werth put forward the hypothesis of the existence of two allotropic forms of iron: α-iron, stable at ordinary temperatures, and β-iron, stable at high temperatures. The Author

describes some experiments which go to confirm this view. Some of them recall the familiar facts of recalescence, while others show that recalescence is accompanied by a certain retardation in the compression, which depends greatly upon the manner in which the iron is cooled down from temperatures above 850°. The iron experimented upon was nearly pure and quite free from carbon, though it contained traces of phosphorus. If this iron is subjected to a pressure of 18 kilograms per square millimetre it shows a certain permanent compression. When released and then subjected to the same pressure, no further compression sets in until the previous maximum pressure is attained. When the release has lasted several hours, the specimen will support a much higher pressure than that previously attained without giving way. Sudden cooling after heating to 850° eliminates the properties described.

E. E. F.

Reflecting-Power of Electro-deposited Metals.

S. COWPER-COLES.

(Electrician, vol. xliv., December 15, 1899, p. 267.)

Silver was deposited on glass and backed with copper, the deposit then separated from the glass, and the silver coated with the respective metal. The tests were made with the help of a Bunsen photometer and pentane standard lamps. If the reflecting power of silver is 100, chromium is 100, platinum 74, palladium 64; for chemical rays and astro-photography platinum and palladium appear, however, superior to silver. Silver is, moreover, soon tarnished in proximity to an arc lamp, whilst palladium keeps its reflecting power. Nickel is unsuitable for arc lamps. When a polished brass plate is silvered, and then thinly gilded and finished, and finally coated with a very thin film of palladium, the reflecting powers are: gold 77, palladium 63, *i.e.*, almost the full value for palladium, although the gold could distinctly be seen through it. The angles of incidence are not stated.

H. B.

Feed-Water Heaters for Locomotives. C. M. MUCHNICK.

(Mechanical Engineer, vol. iv., October 28, 1899, pp. 637, 638. From the American Engineer and Railroad Journal, October, 1899.)

The Author describes two feed-water heaters for locomotives, used on the Paris-Orleans Railway and the Western Railway of France respectively. Lencauchez, engineer of the Paris-Orleans

Railway, designed a heater combined with an oil-separator. The exhaust steam taken from each cylinder is led into an oil-separator formed of a number of hollowed-out plates, assembled in such a manner that the steam has to make several up-and-down courses, leaving the oil on the hollowed-out portions of the plates. The steam thus purified passes into the heater proper, where it comes in contact with the cold water which falls, fountain-like, over a series of trays, each having a finely divided toothed edge. The division of the cold feed water into very small streamlets facilitates the rapid mixture of the cold water and steam. A pump then forces the feed water into the boiler at a temperature of 192°–203° F. The feed heater is provided with check valve, safety valve, and gauge glass.

In the feed-water heater designed by Chapsal, engineer of the Western Railway of France, the cold feed water passes over a series of cones in which steam circulates. Thin deposits from the impure feed water are formed on the surface of the cone, and when broken by the contraction of the latter accumulate round the bottom edges of the cones. It was found that the deposits of laminated tartar, when weighed in a dry state, varied from 22 lbs. to 44 lbs. for a running distance of 1,875–3,750 miles.

A. S.

Hydraulic Boiler-Test.

(Mechanical Engineers, vol. iv., October 28, 1899, p. 623. From Proceedings of the American Boiler Manufacturers' Association, "Power.")

The boiler was a cylindrical multitubular shell boiler, made of steel plates $\frac{3}{4}$ inch thick, the steel having a tensile strength of 55,000 lbs. Size of boiler, 5 feet diameter and 14 feet long. Tubes of steel, fifty in number, and $3\frac{1}{2}$ inches diameter. The shell was divided into three rings, A, B, and C, the circumference of each containing two plates. The vertical or circumferential ring seams were single-riveted lap-joints; the transverse or horizontal seams were as follows. In ring A, on one side of the boiler, a triple-riveted lap-joint with inside covering strap, and on the other side a quadruple-riveted butt-joint with outside and inside straps. In ring B, a triple-riveted lap-joint, same as in A, and a triple-riveted butt-joint with inside and outside straps. In ring C, a triple-riveted butt-joint, and a quadruple-riveted butt-joint, both having inside and outside straps.

Under a pressure of 450 lbs. per square inch, the shell became $\frac{1}{8}$ shorter than normal size, whilst the circumference at the centre of the rings measured as follows: At A, $\frac{1}{8}$ inch longer; at B, $\frac{3}{8}$ inch longer; at C, $\frac{1}{4}$ inch longer, the boiler remaining tight. At 650 lbs. pressure the boiler became $\frac{3}{8}$ inch shorter, at ring A the circumference increased to $2\frac{1}{4}$ inches above normal size, at B

$3\frac{3}{8}$ inches, and at C $2\frac{1}{4}$ inches. The boiler then leaked at the rivets. At 725 lbs. pressure the vertical seam between rings A and B, and the butt-joint in ring B showed cracks.

F. J. R.

Tests of Machinery on Board Ship.

(Mechanical Engineer, vol. iv., October 28, 1899, pp. 626–629. From B. C. Bryan and W. W. White, of U.S. Navy, in Journal American Society of Naval Architects.)

These tests give economic results obtained from the water-tube boilers and the main and auxiliary engines of the American lake steamer "Pennsylvania," the boilers having been fired by a mechanical underfed stoker, using an inferior quality of slack coal, with forced draught from a Sturtevant blowing-fan which delivered the air through tuyere blocks—no air entering the fire from the ashpit. A test sample of the coal yielded calorific power equal to 11,790 British thermal units per pound when dry. The quantity of steam used by each of the auxiliary engines, and also the amount required to work the stokers, were, in addition, separately ascertained.

The boilers were of the Babcock and Wilcox marine type, with generating tubes 2 inches in diameter, No. 10 B.W.G. in thickness; each boiler occupying a space of 9 feet 3 inches long, 12 feet 6 inches wide, and 16 feet 8 inches high, and having 3,000 square feet of heating surface. They weighed, without water, 145,860 lbs. (about 65 tons), and with water, 179,352 lbs. The working steam pressure was 250 lbs. per square inch. The weight of each stoker complete was about 3,500 lbs. The coal was fed continuously from a hopper by a screw conveyor into the central magazine of the stoker, in which it was gradually pushed upwards until it covered the tuyeres or air-blocks through which the fan-blast was directed, both towards the central magazine and towards the outside of the fire. Each stoker had a side door through which the fuel on the dead grate was sliced at about twenty-minute intervals, and thoroughly clinkered and cleaned every 6 hours. These doors also permitted stoking by hand when desired, or in case of any break-down of the mechanical-feeding arrangement, but their opening afforded the only occasions on which smoke was produced. The Table on p. 417 is a summary of the tests made—those marked No. 6 (*a*, *b* and *c*) having been of short duration, to show the effect of reduced boiler pressure.

The main engines were of the usual vertical, inverted, direct-acting type, arranged for quadruple expansion, with a jet condenser —the maximum H.P. being 1,600. The original Paper gives details of sizes and make of the various parts of the machinery.

The average quantity of steam consumed per hour by the various auxiliary engines, which were mostly compound engines (excluding

SUMMARY OF TESTS OF MACHINERY ON STEAMER "PENNSYLVANIA."

Number of test	1	2	3	4	5	6a	6b	6c
Date (1899)	May 28[1]	May 30	{ May 30–31[2] }	May 31[3]	June 1[4]	June 1	June 1	June 1
Duration of test, hours	6	6	6	6	6	3	2	1
Average boiler pressure, gauge	242·0	244·2	240·8	245·3	245·0	197·4	129·8	108·3
Main engines, steam pressure at engines	239·4	238·1	237·2	241·8	241·8	193·4	125·8	104·3
Vacuum, inches	24·35	23·56	22·73	22·71	23·67	23·40	21·60	21·16
Cut-off in high-pressure cylinder	0·644	0·658	0·798	0·542	0·656	0·656	0·656	0·656
M.E.P. reduced to low-pressure cylinder	31·48	31·70	36·93	26·24	32·01	25·71	15·59	11·87
Revolutions	77·33	74·45	79·44	66·31	73·74	67·10	51·02	44·93
Indicated HP.	1,206·71	1,169·77	1,455·04	862·78	1,168·88	855 87	394·94	264·89
Feed water, average temperature leaving heater	222	213·2	219	226·5	181·5	200·1	217	218
Total lbs. fed to boilers	122,439	116,136	146,089	89,566	98,026	45,937	18,390	7,615
Used by main engines	103,509	100,167	125,711	76,351	..	38,818	13,630	5,303
Used by auxiliaries and stokers	18,930	15,969	20,378	13,215	..	7,119	4,760	2,312
Lbs. per hour—main engines—total	17,252	16,694	20,952	12,725	..	12,939	6,815	5,303
Main engines—per I.HP.	14·80	14·27	14·40	14·75	..	15·12	17·26	20·02
Auxiliaries—total	3,155·0	2,661·5	3,396·3	2,202·5	..	2,373·0	2,380·0	2,312·0
Per I.HP. developed by main engines	2·61	2·28	2·33	2·55	..	2·77	6·02	8·73
Total per I.HP. developed by main engines	16·91	16·55	16·73	17·30	16·77	17·89	23·28	28·75
Exhaust steam actually sent to feed heater[5]	14·78	13·02	13·08	13·83	..	10·59	17·41	18·79
Total steam used by auxiliaries, per cent.	15·46	13·75	13·95	14·75	..	15·50	25·88	30·36
Coal, total, lbs.	14,400	14,200	18,000	11,800	14,750	..	..	..
Per cent. of moisture	3·3	3·3	3·3	3·3	3·3	..	..	..
Total, dry, lbs.	13,925	13,731	17,406	11,411	14,263	..	..	..
Total, dry, per hour, lbs.	2,321	2,289	2,901	1,902	2,377	..	..	..
Total, dry, per I.HP. hour for main engines	1·63	1·69	1·72	1·88	..	..	..	..
Total, dry, per hour for all machinery in use	1·92	1·96	1·99	2·20	2·03	..	..	..
Refuse, total	2,183	2,575	3,800	2,463	..	..	..	..
Per cent. in dry coal	15·68	18·75	21·83	21·58	..	..	..	..
Water evaporated, per lb., dry coal, actual conditions	8·79	8·46	8·39	7·85	8·25	..	..	..
" " " " " from and at 212°	9·24	8·97	8·85	8·21	9·02	..	..	..
" " " combustible, actual conditions	10·43	10·41	10·74	10·01	..	..	..	..
" " " " from and at 212°	10·96	11·03	11·32	10·74	..	..	..	..

[1] Preliminary tests; weight of coal used unreliable. [2] Auxiliary water exhausted to atmosphere by blower equal 432·8 lbs.
[3] Leak around gland of feed pump during test equal 396 lbs. [4] Total feed water weighed only during five hours of test.
[5] Given in per cent. of total steam used for all purposes.

the stoker motors), is shown by the following Table of results of tests made on May 28 :—

Auxiliary.	Steam Consumption per Hour.			
	Table I.	Table II.	Table III.	Table IV.
	Lbs.	Lbs.	Lbs.	Lbs.
Air pump	721	715	828	613
Feed pump	487	468	595	350
Bilge pump	275	275	320	240
Water-service pump . .	146	154	156	150
Auxiliary pump . . .	330	..	..	..
Starboard dynamo . . .	..	480	480	..
Port dynamo	671	..	..	..
Steering engine . . .	125	125	125	125
Fire-room blower . . .	622	692	725	550
Total	3,377	2,909	3,229	2,028

In addition to these, the stoker motors showed an average consumption of 23·1 lbs. of steam per hour per motor, the total quantity for all the stokers amounting to 138·6 lbs. per hour. The cost of operating all stokers and blower, based on these results, was 4·29 per cent. of the total steam generated. Allowing for the blower exhaust steam having been passed through the feed heater, the net cost of the stoker installation is taken as equivalent only to 1·68 per cent. of the total steam.

The exhaust steam from the auxiliaries was employed in a feed heater, but when the temperature of the feed water was increased to about 225° F., or higher, the back pressure from the heater shell caused irregular working of the pumps. The upper limit of feed heating appeared to be about 200° F., or an average of approximately 95° F. increase in temperature of the water taken from the hot well, the auxiliaries then consuming about 1·05 per cent. of the total steam generated.

F. J. R.

Test of Railway Generating Plant. E. J. Willis.

(American Institution of Electrical Engineers, Transactions, vol. xvi., October, 1899, pp. 504–508.)

The plant tested consisted of a 300-HP. Campbell-Tell water-tube boiler, a 300-kilowatt, six-pole, G.E. railway generator, direct coupled to a Hoover, Owens and Rentschler horizontal, tandem, compound, condensing engine, running at 100 revolutions per minute. The feed pump and the condenser were operated by a separate boiler, so that all steam generated by the boiler passed through the engine. The water consumption was measured by a Worthington hot-water meter, which was accurately tested before and after the run. The draught of the grate was $\frac{5}{8}$ inch. Read-

ings were taken about every 15 minutes. The load was as follows: 1 hour at 200 amperes, 1 hour at 300, 1 hour at 400, and 1 hour at 500 amperes. Some of the indicator diagrams are given, and the summary of the test, of which figures are given in full, is as follows :—

—	Power.			Evaporation.		Coal Consumed.			Steam.			Efficiencies.		
Load.	Indicated HP.	Electrical HP.	Kilowatts.	Water per lb. of Coal (actual).	Water per lb. of Coal from and at 212° F.	Per Indicated HP. Hour.	Per Electric HP. Hour.	Per Kilowatt Hour.	Per Indicated HP. Hour.	Per Electric HP. Hour.	Per Kilowatt Hour.	Indicated HP. per Electric HP.	Electric HP. per Indicated HP.	Indicated HP. per Kilowatt.
Amperes. 200	216	146	110	10·05	10·71	1·45	2·18	2·90	14·8	21·9	29·1	1·48	0·68	1·96
300	299	220	164	10·8	10·75	1·43	1·94	2·60	15·3	21·9	28·1	1·36	0·74	1·82
400	373	293	219	8·94	9·53	1·54	1·96	2·63	13·8	17·53	23·46	1·27	0·79	1·7(
500	469	369	275	8·57	9·18	1·66	2·11	2·83	14·25	18·1	24·3	1·27	0·79	1·70

E. D. P.

Electric Welding of Rail Joints. R. F. DANFORTH.

(Street Railway Review, vol. ix., September 15, 1899, pp. 575–577.)

(Paper read before the Street Railway Association at New York.)

Welding by bringing the abutting joints to a welding temperature has proved a failure because the homogeneity of the steel is destroyed. At Buffalo the Johnson Company are now using a method by which the ball of the rail never reaches more than a dull-red heat, the weld being made between facing strips at the centre and ends of the splice bars. The surfaces to be welded are pressed together with a pressure of from 3 tons to 35 tons per square inch. After the weld is made, the head of the rail is ground to a true surface by an emery grinder. About 250 amperes at 500 volts are required, being transformed by a rotary converter to 300 volts alternating, and then by static transformer to 5 volts. The contacts are water-jacketed. A machine will weld four joints per hour. Expansion is provided for by special joints every 2,000 feet, and by leaving bolted joints at the special work.

Welded joints require no bonding and do not cost materially more than bolted joints plus bonding. Cast-welded joints give as good a result mechanically, but the electrical contact is not as good. Out of 3,100 welded joints, seventeen had broken.

E. H. C.-H.

INDEX

TO THE

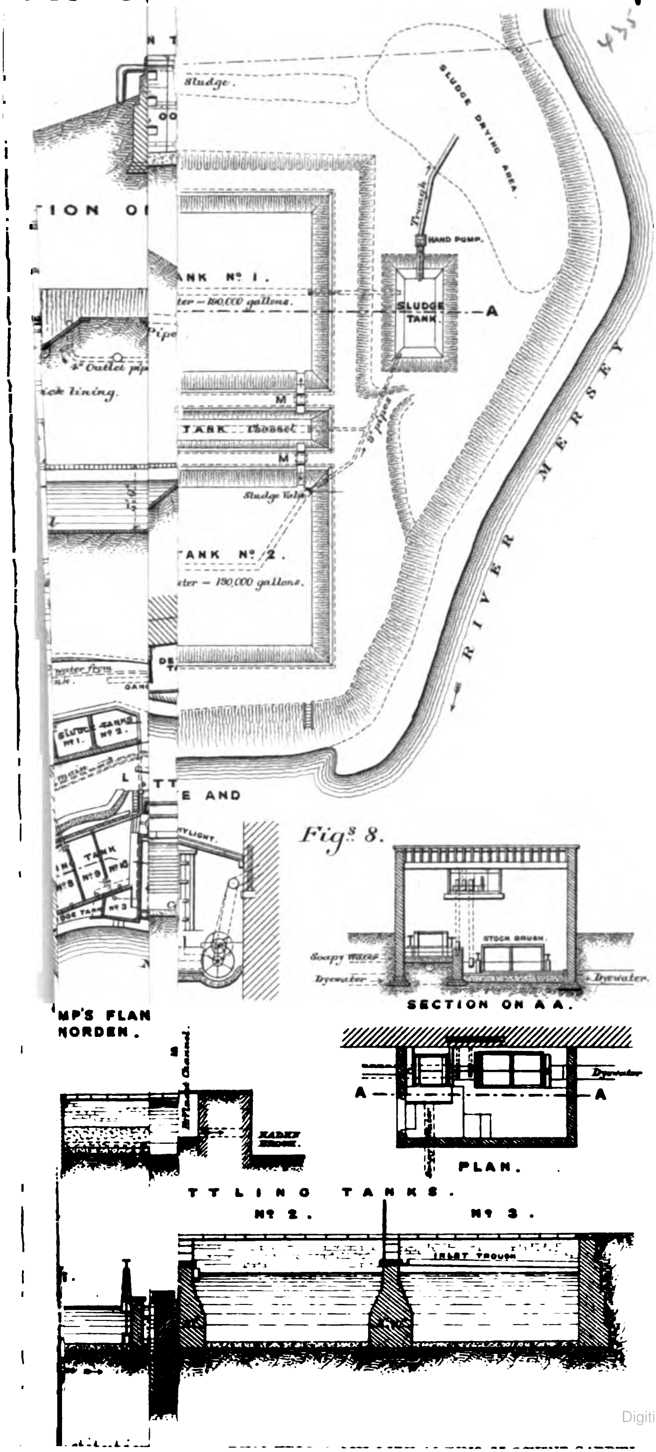
MINUTES OF PROCEEDINGS,

1899–1900.—Part II.

N.B.—Titles in italics refer to Original Papers, and those selected for printing only are further distinguished by the suffix "(S.)." Abstracted Papers are not so indicated.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.

PLATE 1.


Sludge.
SLUDGE DRYING AREA
Trough
HAND PUMP.
TANK Nº 1.
ter – 190,000 gallons.
SLUDGE TANK.
A
Pipe
4" Outlet pip
ick lining.
M
TANK Channel
Sludge Valve
3" pipes
TANK Nº 2.
ter – 190,000 gallons.
RIVER MERSEY
E AND
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Figs. 8.
STOCK BRUSH.
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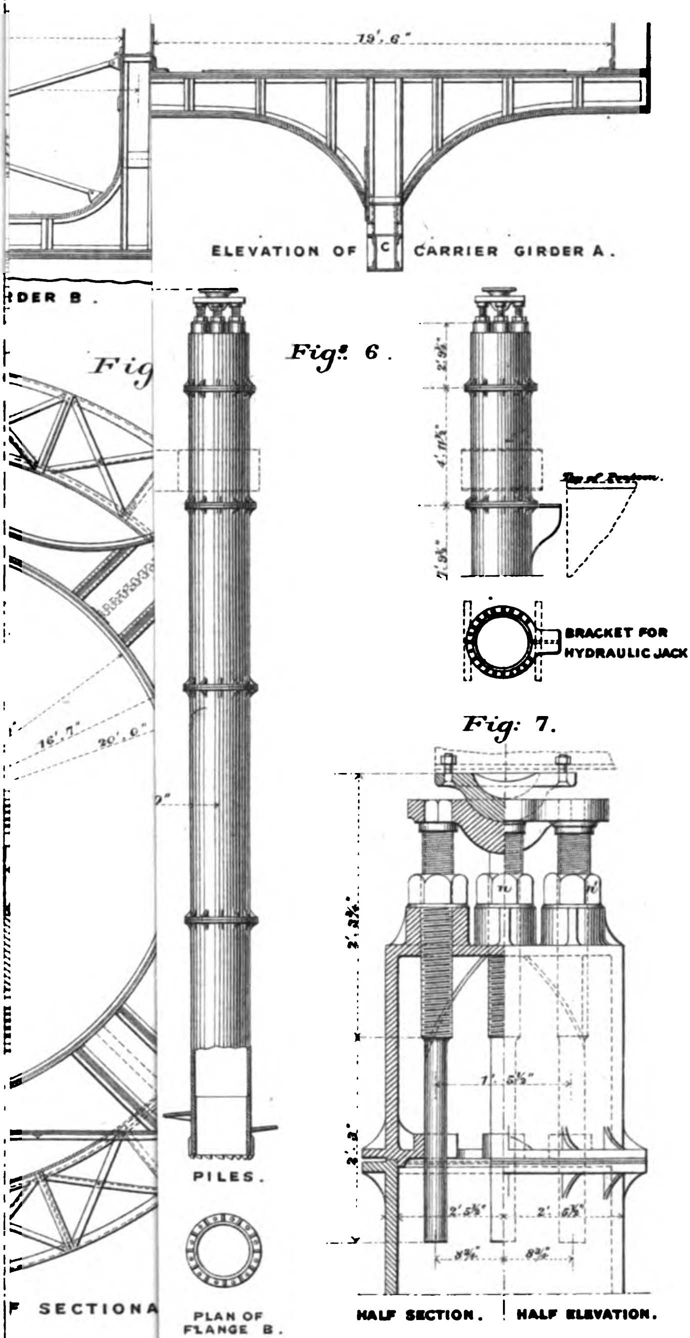
INLET TROUGH



THOS KELL & SON, LITH. 40 KING ST COVENT GARDEN.

Fig.s 11.

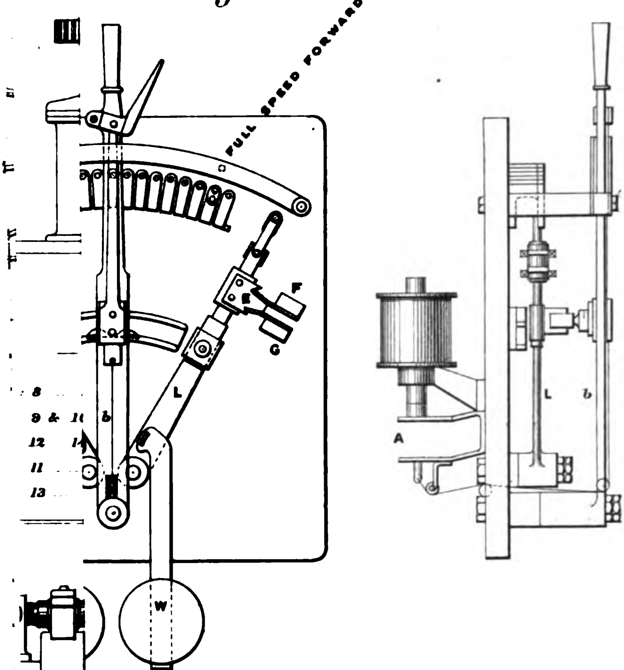
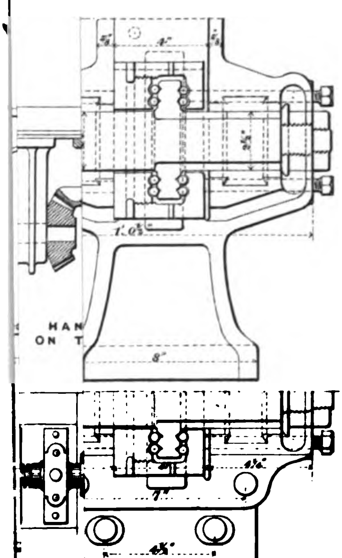
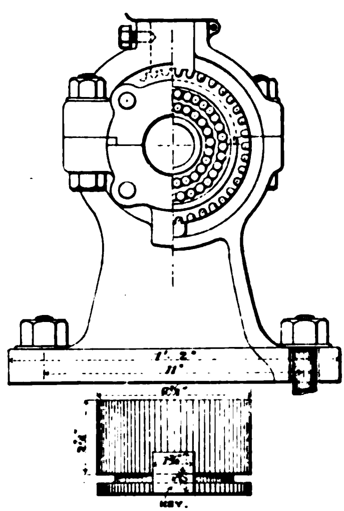


Fig.s 13.



HALF PLAN.



BALL THRUST BEARING.

PLATE 4.

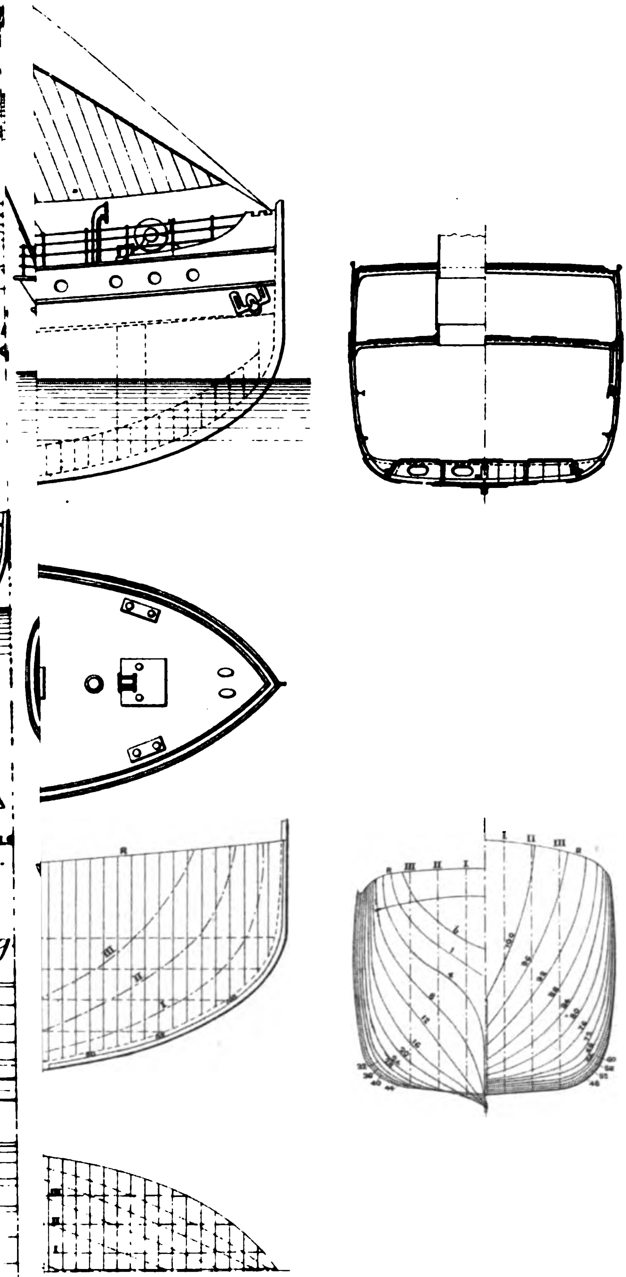
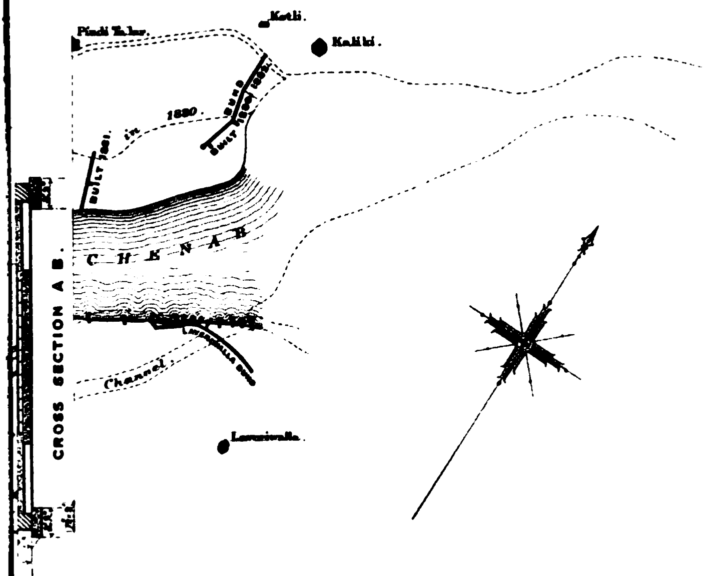
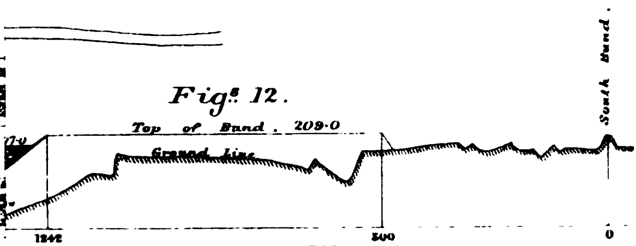


PLATE 5.

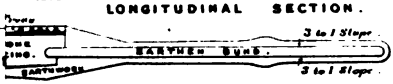
10.



Figs 12.



LONGITUDINAL SECTION.



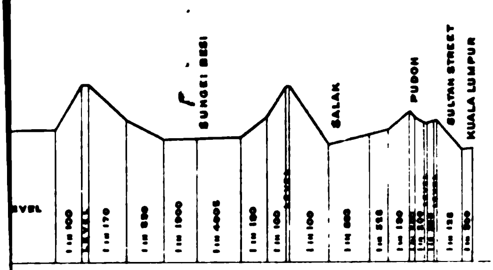
PLAN OF BUND, No 30.

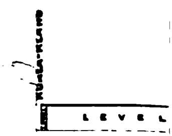
SCALES.

Fig: 1		1	Inch	=	120 Miles.
Figs 4 and 5,		1	"	=	20 Feet.
" 7		1	"	=	10 "
" 10		3/4	"	=	1 Mile.
" 11		1	"	=	40 Feet.
" 12	Horizontal	1	"	=	400 "
"	Vertical	1	"	=	40 "

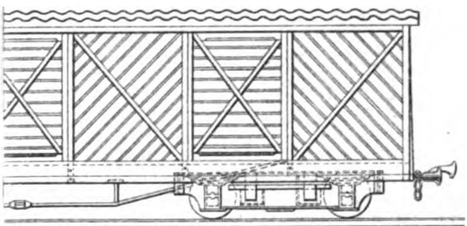
THOS KELL & SON, LITH 40 KING ST COVENT GARDEN.

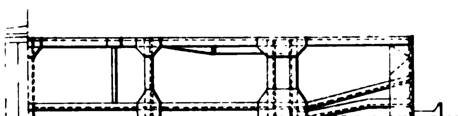
PLATE 6.





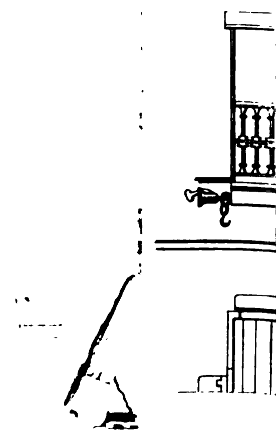
º 6.

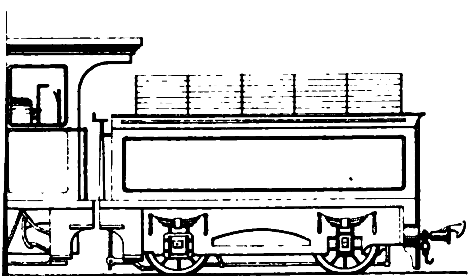


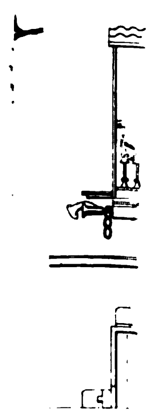


HALF PLAN & FRAME.

GOODS – WAGON.







ER.

ES.

º 2 (*Horizontal*) 1 *Inch* = 6 *Miles*.

(*Vertical*) „ = 200 *Feet*.

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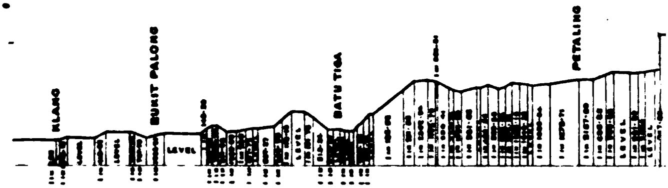
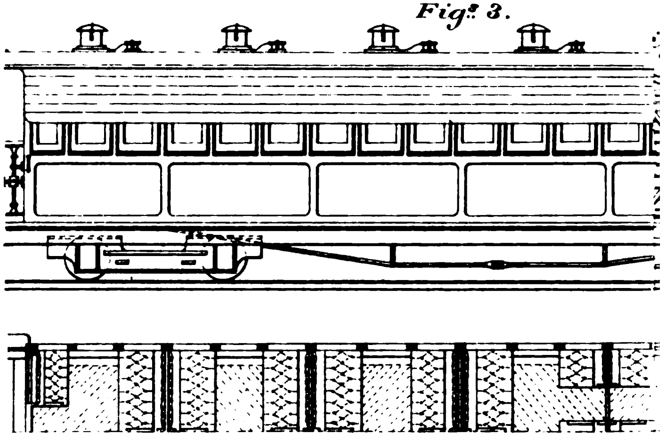


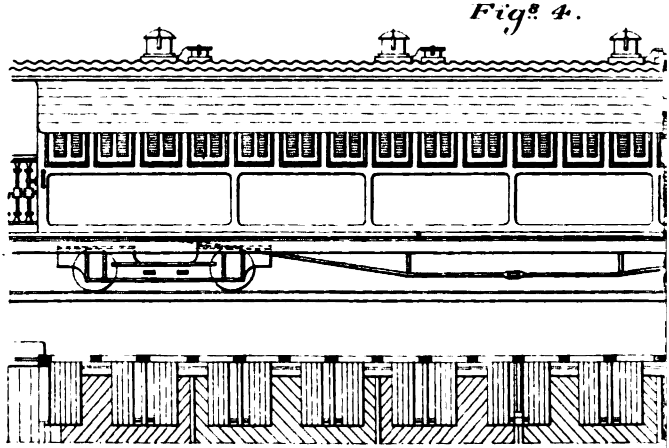
Figs 3.



HALF PLAN.

FIRST CLASS CARRIAGE

Figs 4.



HALF PLAN.

THIRD CLASS CARR

Fig: 1.

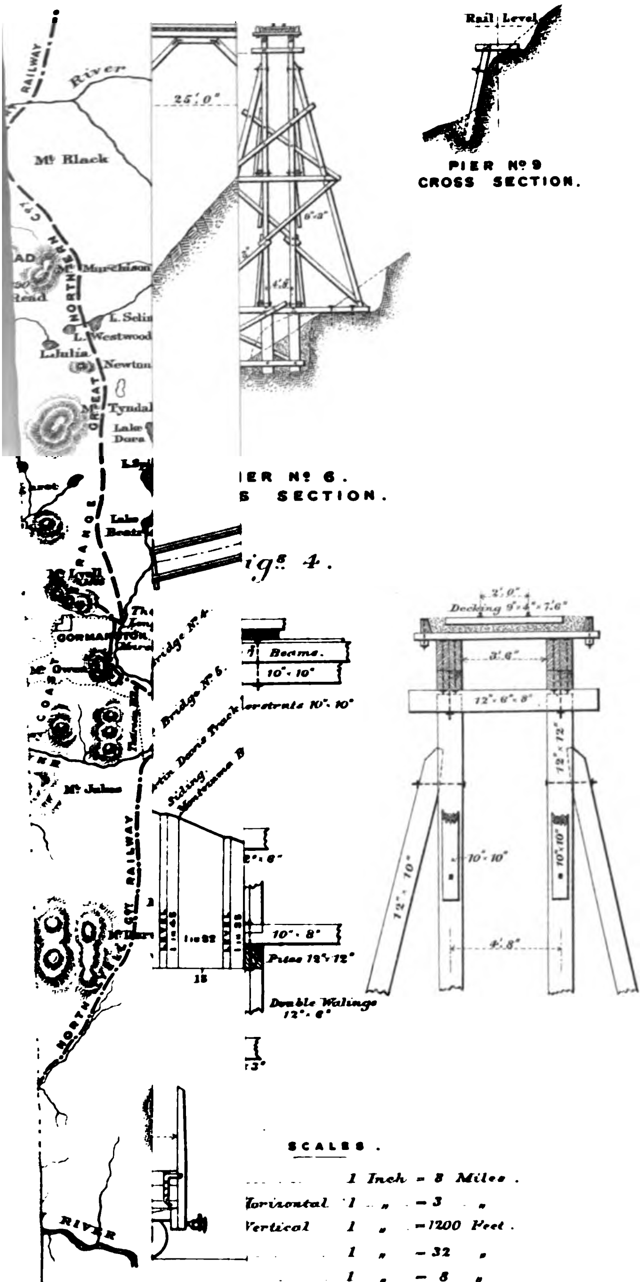
REFERENCE.

Railways opened for Traffic

" under construction

State boundaries

G. H. FOX.



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